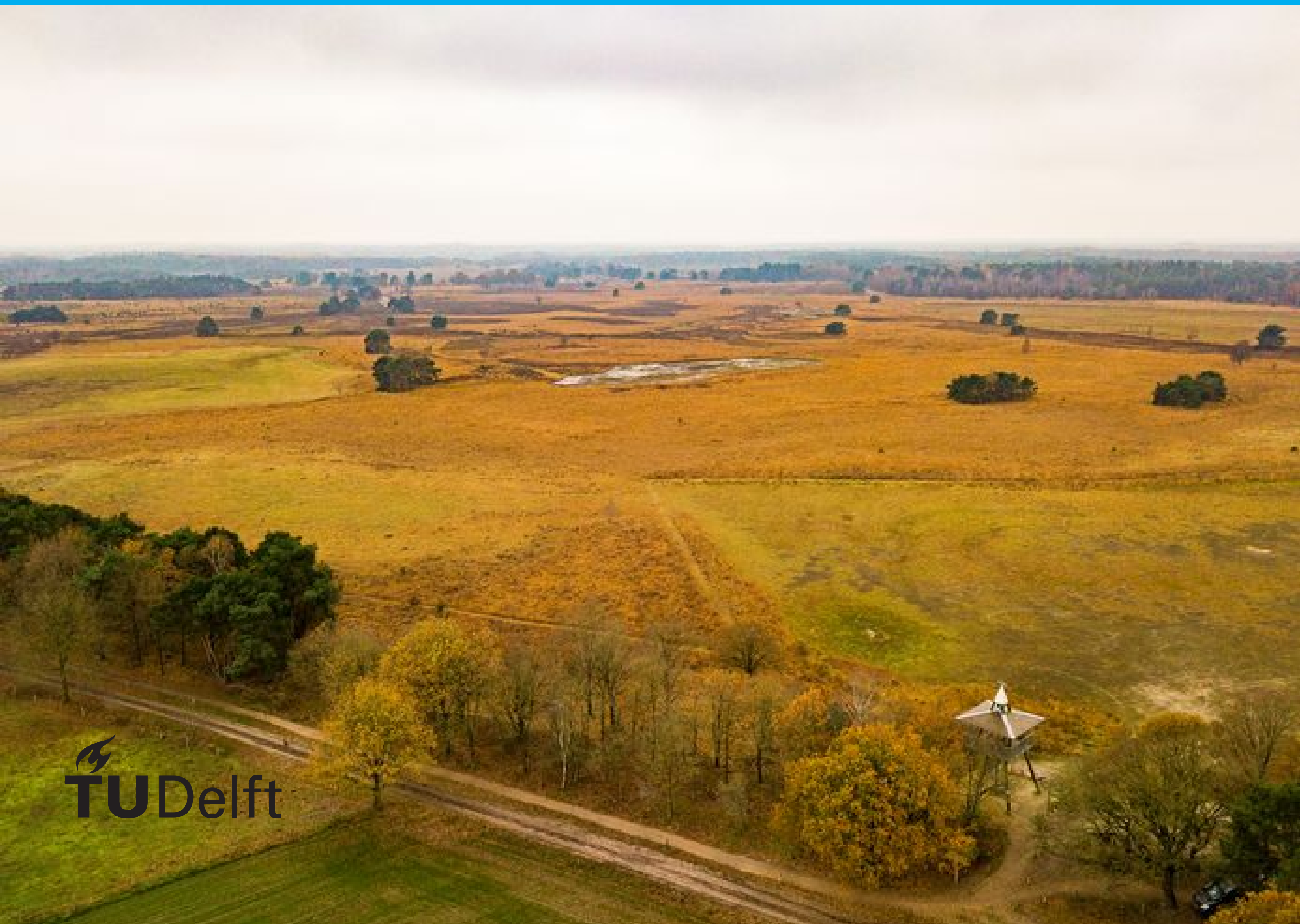
Strategies to decrease water shortage in South-East Brabant

A groundwater model case-study

A.J. van Osnabrugge

MSc Thesis
Master Water Management

Water Resources Section
Delft University of Technology
The Netherlands
May 2022



Acknowledgements

I would like to thank Louis Broersma for this opportunity and his trust in giving me this research project. I am grateful for the guidance he has given me throughout this period and the two-weekly online meeting we had. Although the first project description was focused on a different result, I think I can say for both of us that the direction this research took resulted in useful outcomes for the Water board. From the Water board I would like to thank Tim and Heleen who supported me with questions about their model and gave me enough data to work with. Next to Tim and Heleen I would like to thank their coworkers who I met two times to think along in the process of finding interventions and discussing the results.

From the TU Delft I would like to thank my supervisors Olivier Hoes and Jos Timmermans for guiding me in the scientific process of my thesis and being there if I needed. An their feedback, together with Remko Uijlenhoet, during our four meetings.

Lastly I would like to thank my fellow students, friends, boyfriend and family. They supported me during this long period which didn't seem to end. They encouraged me to keep going and keep working and keep striving for the final document.

Abstract

The Netherlands has suffered form three successive dry summers resulting in a lowering of the groundwater table, causing water shortage. Also in the area of Water Board De Dommel, located within the province of Brabant, water shortage is a common problem. This results in water abstraction restrictions for farmers in the crop season every year. With climate change the precipitation pattern in the Netherlands will change, resulting in longer dry periods during summertime. Water Board De Dommel is searching for strategies to decrease this water shortage. These strategies need to be tested for future climate scenarios. This research tests different interventions for two specific areas within De Dommel. These areas differ in land-use, location in the catchment, geo(hydro)logy and infrastructure. This research answers the following research question: How does the groundwater of two different areas within Waterschap De Dommel react to different interventions to prevent water shortage in long-term future scenarios?

To find the answer to this research question a stationary groundwater model (iMOD) is used. In this model the different interventions are tested with four climate scenarios from the KNMI. These interventions take place in the top layers of the subsoil. Next to these interventions also three abstraction scenarios are modeled, to see the effect of changes in deeper aquifer layers. The interventions are tested with three signals from the model: 1) the head of the first aquifer layer, 2) the water balance for both areas for the first aquifer layer as well as the first four aquifer layers combined and 3) the flow paths. Because models include uncertainties and assumptions, expert judgement is included to test the interventions. The expert judgment is based on historical maps and the location of the interventions. At the end of the research a non-stationary model is used to test the "Brook swamp" intervention. This result is compared to the results of the stationary model of this intervention.

The results show that changes in the top layers of the subsoil have almost no effect on the groundwater in the deeper layers for De Pielis area. More downstream in the catchment, at the Landschotse Heide area, this effect is bigger, because of changes in the upstream area. In the top soil layers the groundwater reacts positive for most interventions for both areas resulting in more water availability. Also in the top layers the effect is bigger at the Landschotse Heide area than at De Pielis area. With the non-stationary model results the groundwater reacts more positive to the "Brook swamp" intervention than for the stationary model. A non-stationary model is therefore better to see how the groundwater reacts to seasonal dependent interventions.

The groundwater reacts differently per areas as well as per intervention. In both areas the groundwater does react positively to most interventions. For the Landschotse Heide area the groundwater reacts more positive than for De Pielis area. For both areas the "higher water level" and "closed ditches" interventions show the most positive reactions of the groundwater.

Based on these results the Water Board is advised to research the effect of enriching the top layer of De Pielis, to see if these top layers can then hold more water. For the Landschotse Heide the Water Board is advised to decide if agriculture or nature is more important in that area, because these cannot coincide, and reach all demands, in the way it is set-up now.

Contents

List of Figures

List of Tables

1 Introduction

'In the face of deep uncertainty, potential actions nevertheless could be taken in the present to decisively shape the long-term future.' - Lempert et al., 2003 (p. 76)

The Netherlands has suffered from three successive dry summers (2018, 2019 and 2020) (Klimaatadaptatie, 2022a) (Huirne, 2020) resulting in a lowering of the groundwater table (Klimaatadaptatie, 2022b). Also the start of spring this year (2022) is one of the driest in the Netherlands since 1906, the start of precipitation measurements in the Netherlands (NOS, 2022) (KNMI, 2022b). Especially the higher parts of the Netherlands, which often consist of sandy soils and thick sandy aquifers suffered from these dry summers. These high parts are completely dependent on precipitation because river water cannot reach these locations. This results in water restrictions for agriculture in these areas during dry periods (Rijkswaterstaat, 2022). Also in Brabant, a province in the South of Holland, water shortage is a common problem the last few years (Stuurman et al., 2020). One of the Water Boards in Brabant, 'Waterschap De Dommel', has restricted water abstraction in a quarter of their area from the first of April till at least the first of October every year (Dommel, 2022c). This is exactly the period for crops to be cultivated. Due to these restrictions agriculture becomes more dependent on precipitation. These restrictions are however necessary for nature and for drinking water companies.

The Dutch infrastructure for waterways has been designed to direct the water as quickly as possible towards the sea because there was sufficient water available and the country would otherwise be prone to flooding. During high intensity (summer) storms water is quickly diverted to the bigger channels, not recharging the groundwater level. Water shortage becomes a bigger problem with the lowering of the groundwater table and insufficient recharge. A transition from diverting excess water towards retaining and infiltrating this access water is therefore necessary to ensure sufficient water in future summers. However, when this water is kept in channels close to agricultural areas crops might drown. A dilemma between 'water level follows function' and 'function follows water level'. Currently the most used management is the 'water level follows function' method, where the water level of waterways is set to the demands for the areas adjacent to the waterways. The function of this land determines the water level. Whereas for the 'function follows water level' method the land-use is adapted to the natural occurring water level in the waterways.

With climate change the precipitation pattern in the Netherlands will change, resulting in longer dry periods during summers (KNMI, 2020), increasing the water shortage during these periods (Rijkswaterstaat, 2022). Water Board De Dommel is already working on a shift towards more climate-resilient infrastructure (like reintroducing meandering streams) but most of this transition is still conceptual. Because this transition is still very new, research needs to be done to see which changes in the infrastructure yield the best results.

The hydrological department of De Dommel has modeled some extreme interventions in their groundwater model for a dry and a wet year. For some interventions the groundwater table did not change significantly while they could see that seepage was increasing. The results of their modelling shows the potential for modelling interventions to decrease water shortage. It also shows that only taking the groundwater level as a signal to define a good working intervention might not be sufficient. This research will therefore focus on more signals to check the interventions.

1.1. Drought vs. water shortage

To understand the problems caused by dry years a distinction is made between the concepts drought and water shortage. In this paragraph the two concepts are explained. Drought is a natural phenomenon. Wilhite and Glantz (1985) describe it as: ‘a condition relative to some long-term average condition of balance between rainfall and evapotranspiration in a particular area, a condition often perceived as “normal”’. Average rainfall however does not give an adequate statistical measure of the rainfall characteristics in a region (Wilhite & Glantz, 1985). Drought is also described as an exceptional lack of water compared with normal condition (Van Loon et al., 2016).

Drought is also difficult to predict because it is a ‘creeping phenomenon’ (Wilhite & Glantz, 1985), only when it has past, or when crops/plants are wilting or dying, we know we had a drought (Tannehill, 1947). Besides that, drought is dependent on the evaporation, which is difficult to predict because it is a result of a lot of factors (KNMI, 2022a).

How severe a drought will be is also difficult to determine. Also its effects on society and the environment are difficult to identify and quantify. It does not only depend on the duration, intensity and geographical extent of a period of drought, but also on the water demands of vegetation and human activities (Wilhite & Glantz, 1985). Therefore, drought should not be confused with water shortage, which is the over-exploitation of water resources when there is an imbalance between water demand and water supply (Van Loon & Van Lanen, 2013).

1.2. This research

In this research strategies to decrease water shortage are tested for different future climate scenarios with a groundwater model. All strategies and climate scenarios will be modeled with a stationary model and one strategy will be modeled with a non-stationary model.

For this research two areas within the area of Water Board De Dommel are selected. Figure 1.1 shows the location of Water Board De Dommel within the Netherlands. One of these areas, De Pielis, is located at the border with Belgium and positioned on a thick sand layer at high elevation. The area has a mild slope and is crossed by a small waterway, the Goorloop. This area is one of the sources of the Grote Beerze catchment (see Figure 1.2). This area is completely dependent on precipitation for its water intake, while 70% of this area is used for agricultural purposes.

The second area, the Landschotse Heide, is located more downstream in the Grote Beerze catchment (see Figure 1.2) at lower elevation and with more clay layers in the subsoil. This is a nature area (heath), surrounded by agricultural land and enclosed by the Grote and the Kleine Beerze. Unlike De Pielis there is water inflow from upstream areas as well as precipitation.

Both areas suffered from the dry summers and were therefore selected for this research. They were also selected because of their differences in location within the catchment, in composition of the subsoil and in land-use. All interventions tested in this research will be tested for both areas. This way the results for both areas can be compared and linked to the characteristics of these areas.

1.3. Long term policy analysis

’Long term policy analysis is a way to help policymakers whose actions may have significant implications decades into the future make systematic, well-informed decisions’ (Lempert et al., 2003, p.xii).

Long term policy analysis (LTPA) is ’one of the most stressing challenges’ in the decision-making under conditions of deep uncertainty genre (Lempert et al., 2003, p.43).

Quantitative analysis is rarely done for long-term time horizons, because it is hard to predict what will happen when a lot of factors might have an impact on the future. Therewith, long-term benefits are in most cases less important than short-term benefits. ’People do not conduct systematic LTPA because no one knows how to do it credibly’ (Lempert et al., 2003, p.2).

With climate change there are some quantitative long-term predictions (IPCC et al., 2022). There are however still four different scenarios, making it only slightly less difficult to do LTPA.

LTPA aims to identify, assess, and choose among near-term actions that shape options available to future generations. Lempert et al., 2003 state that the best response to deep uncertainty is often a plan or strategy that works for a variety of different futures, a no-regret strategy, instead of an optimized plan or strategy for

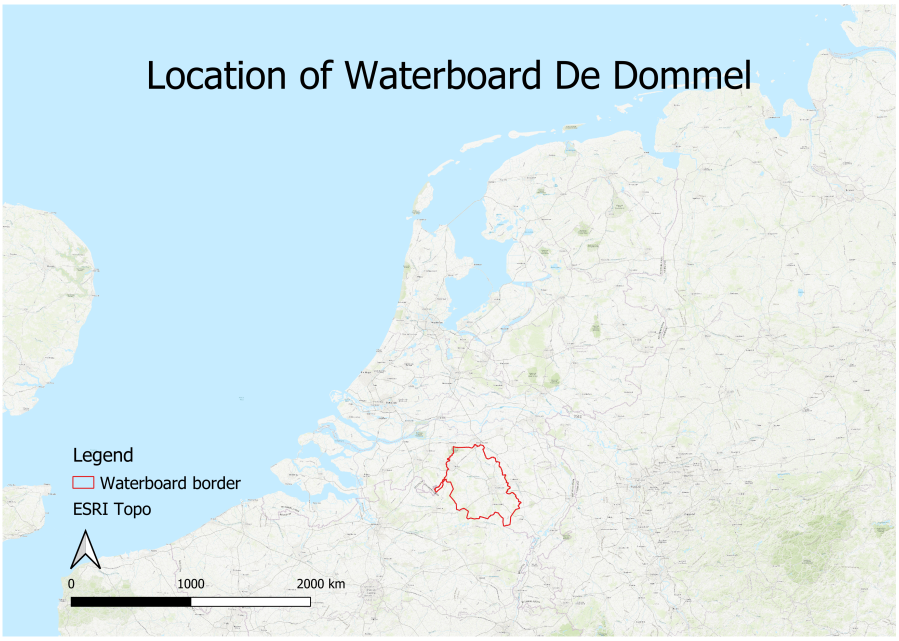


Figure 1.1: Map of the Netherlands with in Red the border of Water Board De Dommel.

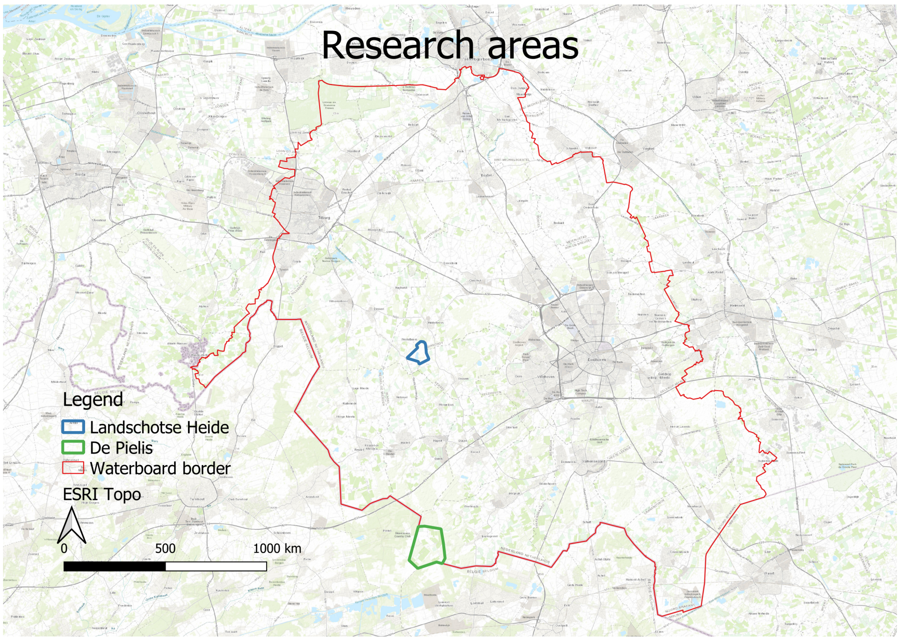


Figure 1.2: Map of Water Board De Dommel with in Blue the Landschotse Heide and in Green De Pielis areas.

one particular predicted future. An addition is the capability of changing or evolving the plan or strategy over time when new information comes up.

In conditions of deep uncertainty computer simulations can be used to generate a large ensemble of possible scenarios of the future. With these different future scenarios near-term policy options can be tested on robustness over a wide range of future scenarios (Lempert et al., 2003).

In this research a foundation will be formed for adaptation pathways to help with LTPA. The interventions will be tested in robustness for four future climate scenarios with the groundwater model.

1.4. Research question

The main research question for this research is:
How does the groundwater of two different areas within Waterschap De Dommel react to different interventions to prevent water shortage in long-term future scenarios?

This question will be answered using the following sub-questions:

- What are the differences between the areas?
- How have these areas changed over time?
- How do the signals react to the interventions?
- What is the difference in the results of the interventions for both areas?
- How can this difference be explained?

1.5. Outline

In Chapter 2 the framework which is used for this research is explained as well as the methodology used to retrieve the answers to the sub- and main research questions.. In Chapter 3 the two areas used for this this research are described. Chapter 4 then shows the results of this research per sub-topic and in Chapter 5 a conclusion is drawn and a discussion on the research can be found. In the Appendix extra background information and model results are shown.

2
Methodology

In this Chapter the XLRM framework is explained and it is described how this is used for this research. Apart from literature research, the modelling software iMOD, QGIS, Google Earth Engine and expert judgement is used to retrieve the results for this research.

2.1. XLRM Framework

In this research different interventions to decrease water shortage will be tested for future scenarios. These interventions could eventually lead to pathways. Pathways are a set of actions taken over time (Marchau et al., 2019). Adaptation pathways describe a sequence of policies that enable policymakers to explore options for adapting to changes in the environment and or societal conditions (Haasnoot et al., 2012). They are thus a set of interventions over time, which may change due to new information. Over time, incidents can provoke policy responses which may change societal viewpoints. Adaptation, over the course of time, is therefore dependent on the evolution of a pathway (Haasnoot et al., 2012). When using an adaptive approach, the possibility to change plans due to new insights is integrated in the planning process (Lempert et al., 2003). In this research the interventions to change groundwater level and groundwater flow are modeled and tested for different future scenarios.

This research is structured using the XLRM framework. This framework is designed to structure decision problems under deep uncertainty. It quantifies four types of factors (Lempert et al., 2003):

1. Exogenous uncertainties (X): factors outside the control of decisionmakers but may be important in determining the success of a design or their strategies. In this research these are the climate and water abstraction scenarios;

2. Policy levers (L): actions that comprise the alternative strategies decisionmakers are considering. In this reasearch these are the interventions to decrease water shortage;

3. Relationships (R): describe the ways in which the various factors relate to one another, they govern how the future might evolve based on the decisionmakers' choices of the policy levers and the manifestation of the exogenous uncertainties, especially for the attributes addressed by the measures. In this research this will be done with a groundwater model; and

4. Measures (M): performance standards that decisionmakers and stakeholders would use to decide on the desirability of the various alternative designs. Because the word measure has two definitions (action or criterion) the word signal will be used to describe this factor in this research. In this research the signals are the head in the aquifer layers, a water balance and flow paths.

These four factors are worked out for this research below. It is an interaction of these four factors that is a continuous process. Policy levers might be adapted based on new information about the exogenous uncertainties. Because of this interaction the factors are structured in the order of activities (LRXM) for this research and not in the order as mentioned above.

Because these factors interact Figure 2.7 shows the way how they interact for this research. This is an adapted version of the XLRM framework as schematised in Lempert et al., 2003.

2.2. Policy levers (L)

The Water Board has some ideas for interventions to decrease the water shortage in De Dommel area (see Figure 2.1), these will be tested for the different future scenarios. The effect of these interventions will be modelled using a groundwater model. They will be tested individually as well as combined for both areas. It will be checked first if an intervention is possible for both areas, as it might be possible that due to the differences in the areas an intervention will not be effective for both areas. Next to the interventions in Figure 2.1 other interventions might come up, due to results coming out of the model, or from expert judgement, who might have another view on the groundwater system.

The ideas for the urban areas ('stedelijk gebied' in Figure 2.1) are however not useful for this research as there are only a few farms in De Pielis area and no real urban areas. The interventions for the stream valley ('beekdal' in Figure 2.1) and the rural area ('flank' in Figure 2.1) were translated to possible adjustments in the model. Next to these interventions also interventions were gathered from (news) articles and the book 'Nederland Droogteland' (Didde, 2021).

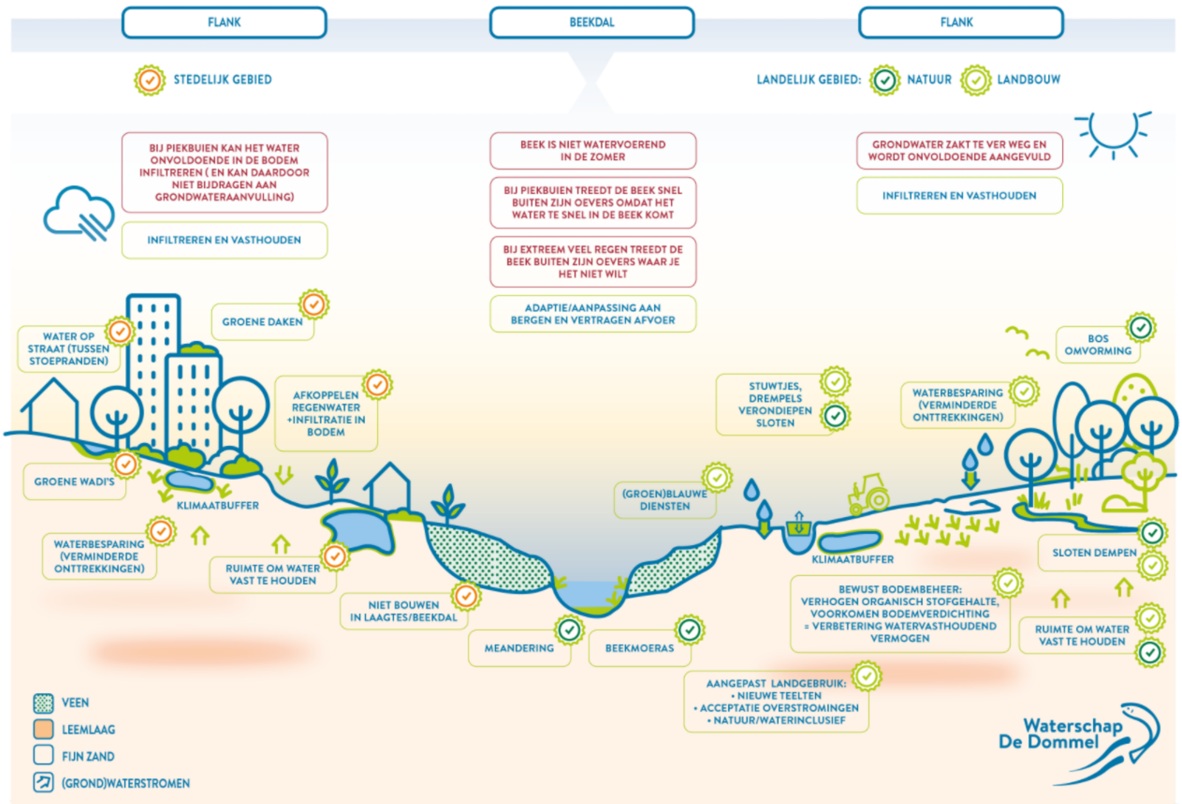


Figure 2.1: Intervention ideas of Water Board De Dommel

2.2.1. Single interventions

The interventions of the Water Board and their changes in the model are shown in Table 2.1. The percentages are the changes compared to the reference year 2018. Below all interventions are described in more detail. This describes how the interventions are implemented in the groundwater model.

Meandering

With this measure some A-waterways have been rerouted to get a more meandering shape. This results in an increased stream length and therefore the flow duration within a system. This measure is added in iMOD by

Table 2.1: Interventions of the Water Board and the corresponding changes in the model

Interventions	Changes in model
Stream valley	
meandering	change position of waterways to historical position
brook swamp	50% width increase of waterway
mowing less/less nourishment	10% discharge decrease
Rural area	
weirs, steps shallowing ditches	water level 0.4m below ground level
water saving (less abstraction)	Adding agricultural abstraction
close ditches	remove B- and C-waterways
climate buffer	water level higher around nature areas/no agriculture

creating new routes for the A-waterways close to the two areas and removing the 'old' routes. A new route was drawn for the Goorloop within the area of De Pielis, as well as for some waterways upstream of Landschotse Heide. Because these waterways have been drawn as new waterways the characteristics of these waterways still had to be connected. These new waterways are given a water level at 0.4m below ground surface, a width of 1.5m and a depth of 0.5m.

Brook swamp
With this measure the width of the A-waterways is doubled and their depth is halved. To model the effect of a brook swamp also the infiltration factor needs to be switched on. This factor is set to 0.3, as advised by hydrologists of Sweco. This is also done for the Base model, to make an accurate comparison.

The water level for the B- and C-waterways is increased in the same way as for the higher water level measure.

Less mowing
With this measure the water level of all waterways is increased with 0.1m. When the water board mows less in the waterways the flow velocity decreases. The folw veleocity can, however, not be changed in the model. When the flow velocity decreases the water level rises (Bernoulli's equation (Krause, 2005)). Therefore this measure is modeled with a higher water level.

Higher water level
With this measure the water level of the A-,B- en C-waterways within the area of De Dommel is increased. The water level in the A-waterways is increased to 0.4m below ground level. For the B- and C-waterways the water level is increased to 0.2m below ground level.

All other aspects of the waterways stay the same as in the Base model. So the bottom, width, conductance and infiltration factor are not changed.

Agricultural abstraction
With this measure water is abstracted from the ground by farmers. This is, however, not easily modeled for the area of interest. The Water board does not have an overview of the amount, discharge, location and depth of agricultural wells. This abstraction is therefore not included in the Base model. This measure is therefore calculated in a different way.

Figures 2.2a and 2.2b show possible groundwater abstraction locations for irrigation purposes in and around De Pielis and Landschotse Heide areas (natuurlijk kaptiaal, 2015). As can be seen there are a lot of groundwater abstraction points in the surroundings of the Landschotse Heide and in the area of De Pielis. This only gives an indication of the locations of groundwater abstraction, there might be more locations because this data dates from 2015. The discharge and depth of these wells is not known. Therefore a simple calculation is done to get an indication of the contribution of the agricultural abstraction to the groundwater level.

The mean highest precipitation deficit during the growing season for the Netherlands is 144 mm for the reference period of the KNMI'14-scenario's (KNMI, 2014). In 2050 this may increase to 187 mm and in 2085 to even 216 mm (KNMI, 2014). Even after the maximum deficit has been reached and the deficit start to decline, there is still a water shortage for crops. This means that for agriculture more irrigation water is needed in a year than the maximum deficit of that year. For this research the maximum deficit is therefore rounded off to a higher value. The abstraction for irrigation for the reference period will therefore be set to 150 mm/y. For the stationary situation this results in 0.41 mm/d. For 2050 en 2085 it will be set to 200 mm/y and 230 mm/y respectively. For the stationary situation this results in 0.55 mm/d and 0.63 mm/d. In reality agricultural wells will likely abstract more water, but this access water will infiltrate into the soil and percolate back to the groundwater. Therefore this extra amount of abstracted water is neglected for this calculation.

As can be seen in Figures 3.8 and 3.7 in Chapter 2, the areas are not completely used for agricultural purposes. When looking at the areas with the 1 km buffer areas about 50% of the land-use is agriculture. For de Pielis the total area with buffer is 2457,163 ha resulting in a groundwater abstraction of 5037,184 m^3/day. For the Landschotse Heide the total area with buffer is 1084,799 ha resulting in a groundwater abstraction of 2223,838 m^3/day.

Close ditches

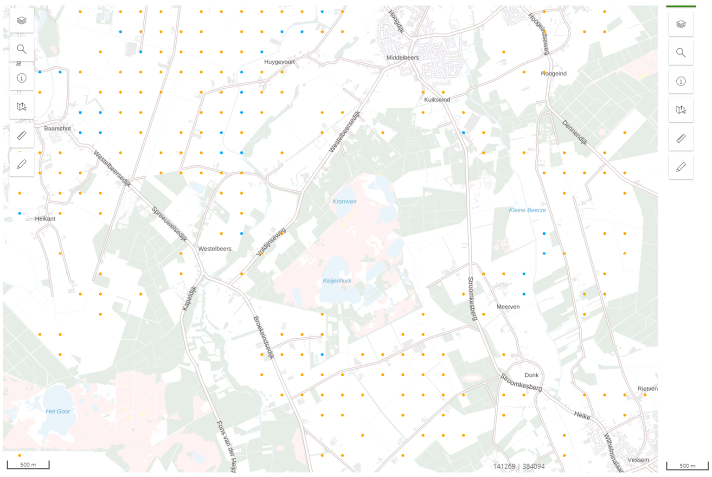
With this measure the B- and C-waterways are filled up. In the model this is simulated as NoData for the B- and C-waterway files. The A-waterways stay the same as in the Base model.

Infiltrating water

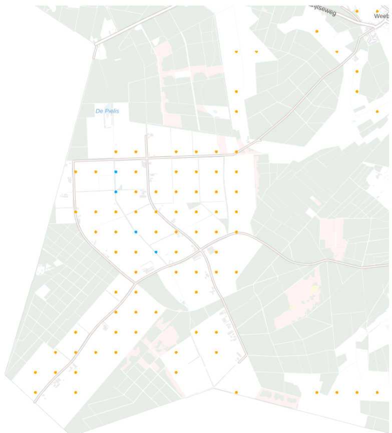
The Water Board De Dommel has several water treatment plants where effluent water is now discharged into waterways. Via these waterways the effluent will flow out of the system very quickly. This effluent can therefore be seen as lost water for the system.

With this measure this effluent will be pumped toward higher places in the system where it can infiltrate. This way the effluent will be kept within the system and can recharge the groundwater level. In this research the effluent is pumped to a location south of Landschotse Heide. This location is the highest point in the surroundings of Landschotse Heide. The effluent will be inserted in the fourth aquifer layer (about 10m deep), just above the first aquitard to ensure that the effluent remains in the top part of the soil.

Figure 2.3 shows the location of the effluent infiltration. There are nine locations close together where at each location 100 m^3/h is infiltrated. This amount is based on the average amount of effluent production of the seven waste water treatment plants within the area of the Dommel (Eindhoven excluded). This means that the same amount of effluent infiltration could be done at six more locations, if desired.



(a) Landschotse Heide



(b) De Pielis

Figure 2.2: Groundwater abstraction locations for irrigation purposes (natuurlijk kaptiaal, 2015)

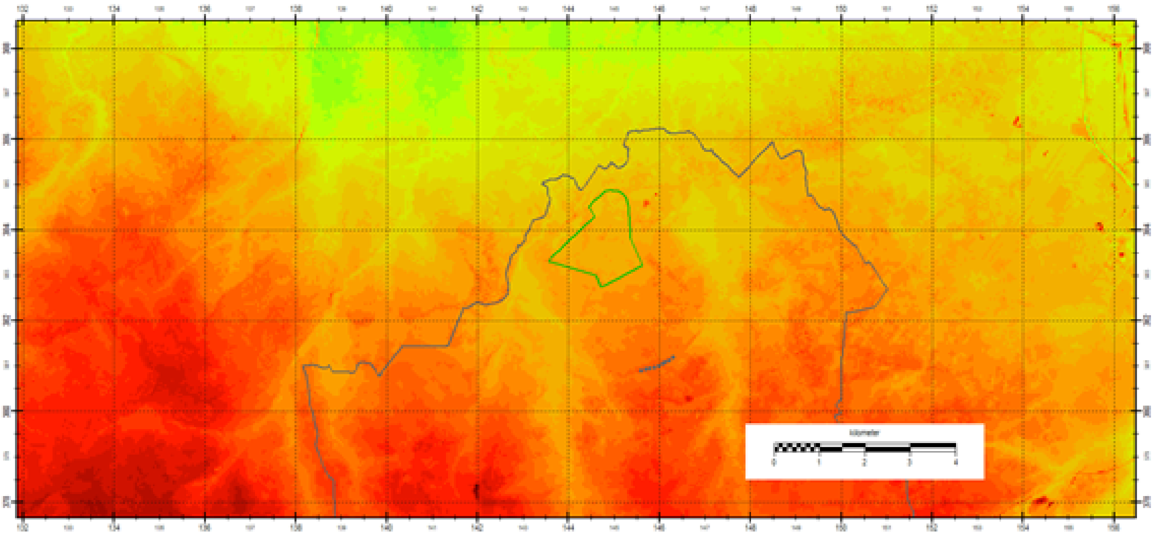


Figure 2.3: Locations for the Effluent infiltration intervention upstream of the Landschotse Heide. The gray dots South of the Landschotse Heide are the nine locations for the effluent infiltration

2.2.2. Combined interventions

In this subsection the results of combinations of the single interventions, described in the previous subsection, are presented.

Higher water levels and closed ditches

With this measure the measures with a higher water level and closed ditches is combined. So the water level in the A-waterways is increased to $0.4m$ below ground surface and the B- and C-waterways are filled up.

Climate buffer

With this measure a climate buffer around the Landschotse Heide is modeled. In this measure the interventions of closed ditches and higher water level (although a bit adjusted) are combined in the buffer area. This buffer area is a strip of $1km$ around the Landschotse Heide. In this strip the B- and C-waterways are filled up and the A-waterways get a water level as high as the ground level.

Climate buffer and effluent infiltration

With this measure the previous measure is combined with the effluent infiltration measure described above. These two measures are close to or within the Landschotse Heide area. It is therefore decided to see what a combination of these two interventions will do for the Landschotse Heide.

2.3. Relationships (R)

Interventions can be model based, based on expert judgement or hybrid. In this research the interventions will be hybrid. In the first phase of the research the interventions will be model based. With a groundwater model interventions will be tested for the uncertainties (described in the next section), where the results will lead to new or adapted interventions. In the second phase, the interventions will be based on expert judgement, where the outcome of the model based interventions will be discussed and adjusted based on expert knowledge. Also new interventions might come up based on expert judgement.

The changes in the groundwater table and the groundwater flow will be due to the interventions. The results will show different changes for different interventions. A groundwater model (iMOD) is used to check what the reaction of the signals to the interventions will be. Via Sweco an iMOD model of the area of the Water Board is provided. This iMOD model is the basis of the model used in this research. This model is based on (geo)hydrological data of 2018. The Water Board has already used this model for extreme interventions for the whole Water Board area based on previous dry and wet years. From that it can be concluded that this model can handle these kind of interventions. It however needs to be tested for future scenarios.

The interventions are first modeled with a stationary model. A stationary model is a model that averages the outcome for a year. This means that daily, monthly and seasonal fluctuations are not shown in the results. After analyzing these results and expert consultation one intervention is chosen to model with a non-stationary model. A non-stationary is a model that does use the daily, monthly and seasonal fluctuations of the input data and gives the results in time-steps. Really detailed non-stationary models even use nanosecond fluctuations. In this research the non-stationary model models the head per day of all 19 aquifer layers for the period 2010-2020.

2.4. Uncertainties (X)

For the XLRM framework a lot of future scenarios should be taken into account. In this research the uncertainties are restricted to four climate scenarios and three big water abstraction scenarios. Because these changes are not actions the Water board can control, they are modeled as future scenarios and not measures. The future climate scenarios are used to test the different measures and their applicability for implementation.

2.4.1. Climate scenarios

Different climate scenarios of the IPCC will be used for two future states, the years 2050 and 2085. The KNMI has calculated the precipitation and evaporation for The Netherlands for these scenarios and time frames (KNMI, klimaat'14). Because the model works with a yearly recharge these future precipitation and evaporation scenarios can be used to alter the model.

Table 2.2 shows the KNMI scenarios for the precipitation and evaporation in percentage and the calculated precipitation, evaporation, recharge and the natural variation in $mm/year$. The natural variation describes the standard deviation of the average yearly precipitation (KNMI, 2019). It can be seen that in almost every scenario the average recharge becomes more. However, when including the natural variation there are also dryer future predictions.

For this research the lowest and highest values of 2050 and 2085 are modeled. These are the 2050GHmin, 2085WHmin and 2050WLmax, 2085GLmax respectively.

Table 2.2: Future climate scenarios for The Netherlands in 2050 and 2085 in $mm/year$, where P: precipitation, E: evaporation, R: recharge (P-E), Min: minimum recharge (R-nv*P-nv*E), Max: maximum recharge (R+nv*P+nv*E) and nv: natural variation.

	1981-2010 reference	2050 GL	GH	WL	WH	2085 GL	GH	WL	WH	nv
P	851	+4%	+2.5%	+5.5%	+5%	+5%	+5%	+6%	+7%	±4.2%
	851	885	872	898	894	894	894	902	911	36
E	559	+3%	+5%	+4%	+7%	+2.5%	+5.5%	+6%	+10%	±1.9%
	559	576	587	581	598	573	590	593	615	11
R	292	309	285	317	296	321	304	309	296	
Min	245	262	**238**	270	249	274	257	262	**249**	
Max	339	356	332	**364**	343	**368**	351	356	343	

2.4.2. Water abstraction scenarios

Besides climate change the water abstractions of the drinking water companies and industry are an uncertainty. This will not be seen as a possible adaptation path in this research and will therefore be included in the future scenarios in three possibilities. These three possibilities are 1) no water abstraction at all, 2) 30% less water abstraction than in 2018 and, 3) 30% more water abstraction than in 2018. The first scenario will probably never happen (because water will always be abstracted for drinking purposes). But this scenario is added because it is a good way to see what the contribution of these abstractions is to the lowering groundwater table. The water abstractions in the Base model are the water abstractions from drink water companies and industry of 2018.

2.5. Measures/Signals (M)

For this research different Signals were chosen to define a good working intervention. These signals are model outputs and expert judgement. The model outputs are the heads in the different aquifers, a water balance of the top layer, a water balance of the four top layers combined and flow paths. The expert judgment signals are the location of the effect in the catchment, the expected effect based on historical maps and if the effects of the model are reasonable. These signals have been selected in consultation with employees of Sweco and the Water Board. The interventions that show positive changes in these signals across different future scenarios will be considered the most promising interventions.

For the non-stationary model the water balance and flow paths will not be used as signals in this research. These signals are too complex take up too much storage space. It would also take a lot of time to generate. Therefore a time series of the head at a few locations (see Figure 2.4 and 2.5) is used as signal.

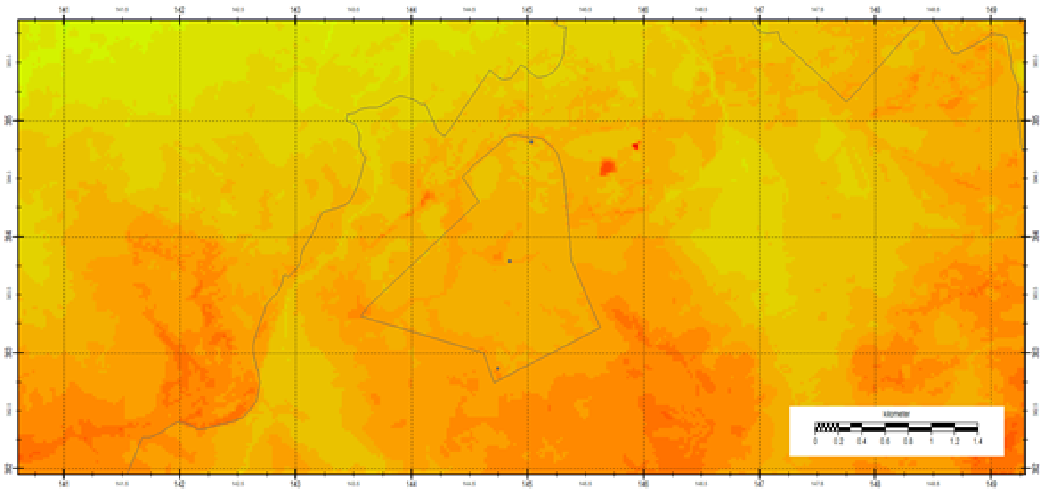


Figure 2.4: Location of the time series for the non-stationary model for the Landschotse Heide (the three gray dots).

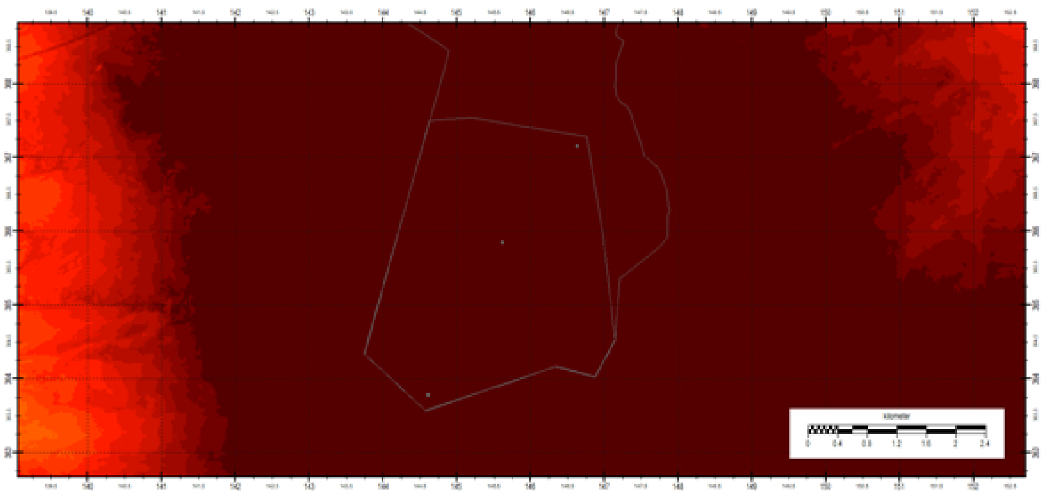


Figure 2.5: Location of the time series for the non-stationary model for de Pielis (the three gray dots).

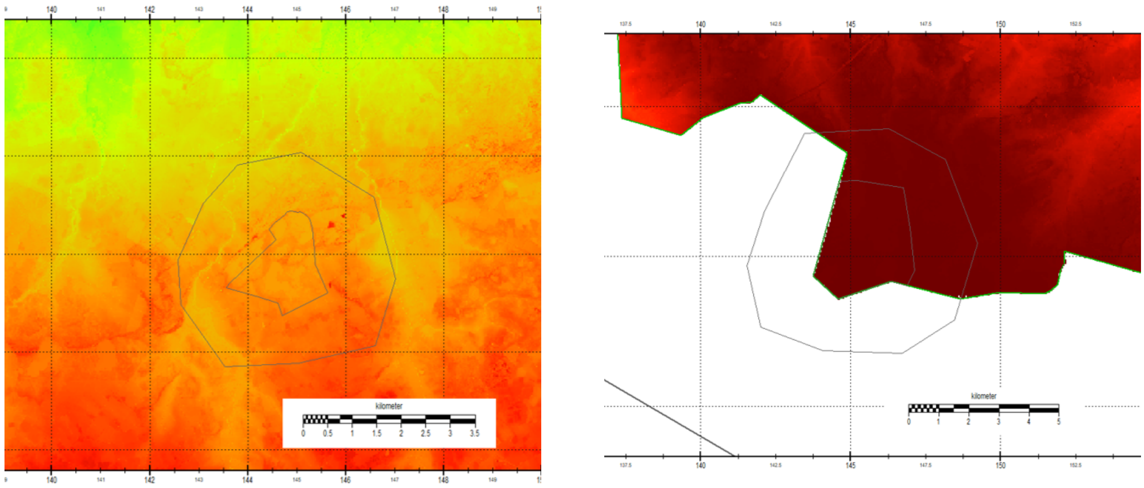
2.5.1. Heads

The goal of the interventions is to decrease the water shortage during summer months. Because this research is about groundwater the signals of a ‘working’ intervention will be a positive change in groundwater level. A positive change means that more water is available and thus the water shortage is less. These signals are chosen because they can be derived as output of the iMOD model.

The iMOD model calculates for all 19 aquifer layers the head. As most interventions are adjustments in the first aquifer layer, only the head of the first aquifer layer is used as a signal in this research.

2.5.2. Water balance

With SIF-iMOD the water balance for each aquifer layer can be calculated. Figures 2.6a and 2.6b show the areas for which the water balances are calculated. Just as for the heads this research focuses on the top aquifer layer. The SIF-iMOD water balance calculator adds the discharge of the waterways to the lowest aquifer layer of which the waterway cuts trough. Therefore also the four top aquifer layers are combined in a water balance. This way the contribution of the waterways is included in the water balances.



(a) Landschotse Heide

(b) de Pielis

Figure 2.6: Calculation areas for the water balance calculations (outer line)

2.5.3. Flow paths

Because the head results only give a vertical change and the water balance only gives a qualitative overview, flow paths are also used as signals. The calculation areas for the water balances are also used for the flow paths. In the top aquifer layer in the calculation area the starting points are located. At each starting point the flow paths start at three different depths within the first aquifer layer.

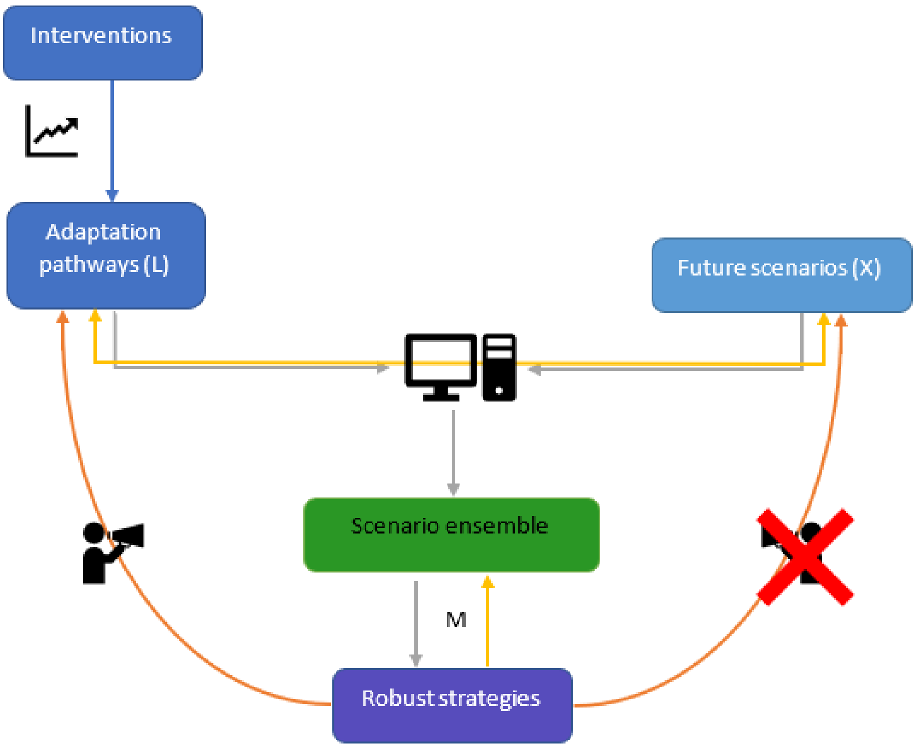


Figure 2.7: Framework schematization

3 Research locations

Two areas at Water Board 'De Dommel' will be the subject of detailed hydrological modelling: Areas 'Landschotse Heide' and 'De Pielis'. Both areas are located within the are where water abstraction is periodical restricted by the Water Board (Dommel, 2022c). In this Chapter the differences of the characteristics of these two areas are described. These areas chosen for this research are chosen for their differing properties: the elevation, profile, land-use, location in the catchment and subsoil. This way the interventions to decrease water shortage can be compared under different hydrological conditions.

3.1. Situation

The area of De Dommel is located in the province of Brabant, in the south of the Netherlands, at the border with Belgium. It neighbours at the North-East border with Waterschap Aa en Maas, at the East border with Waterschap Limburg and at the West border with Waterschap Brabantse Delta.

Figure 3.1 and 3.2 show the topography of the two areas subject to this research. Both areas are located in the same catchment area.

Landschotse Heide

De Landschotse Heide is located east of the city Eindhoven. The area has an elevation between 18.1 and 22.0 $mNAP$ (Esri Nederland, 2021) and has an area of 239 ha (landschap, 2017).

The Landschotse Heide, a nature area, used to be a heath area but is nowadays more looking like a steppe landscape due to water shortage. There used to be a lot of fens filled with water throughout the year, now they are dry for during the biggest part of the year (Today, 2021). There used to be a lot of waterbirds which are rarely seen nowadays (Eindhovensdagblad, 2020).

The area is considered a 'Natte Natuurparel', areas where nature depends on a high water table and good water quality.

De Pielis

De Pielis area is located at the border with Belgium, it has an elevation between 34.1 and 49.5$mNAP$ (Esri Nederland, 2021) and is the highest part of the province Brabant (Eindhovensdagblad, 2008).

The area mostly consists of sandy soil (Dommel, 2022b). It can be seen as a hamlet and has 40 houses with around 100 inhabitants. The area is exactly 1.000 ha.

3.2. Elevation

De Dommel has an elevation between 0.1 and 49.5 $mNAP$ (Esri Nederland, 2021). This can be considered as the higher parts of the Netherlands.

Landschotse Heide

The Landschotse Heide is located in the middle of De Dommel area. The elevation of the Landschotse Heide is around the mean elevation of De Dommel area (see Figure 3.3).

It can be seen, in the elevation map, that at the south border of the Landschotse Heide the elevation is higher, and therefore water flows northward. At the north of the Landschotse Heide the elevation is clearly

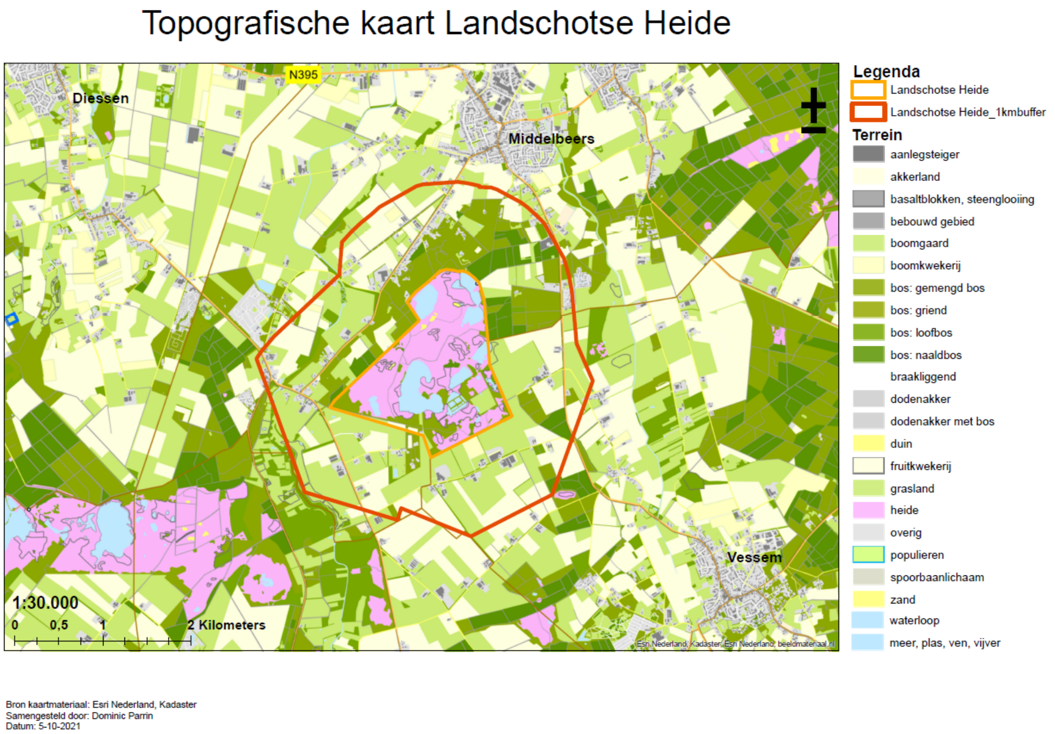


Figure 3.1: Topography of the Landschotse Heide area and its surrounding areas. The orange and red contours indicate the borders of Landschotse Heide and a buffer of 1 km respectively.

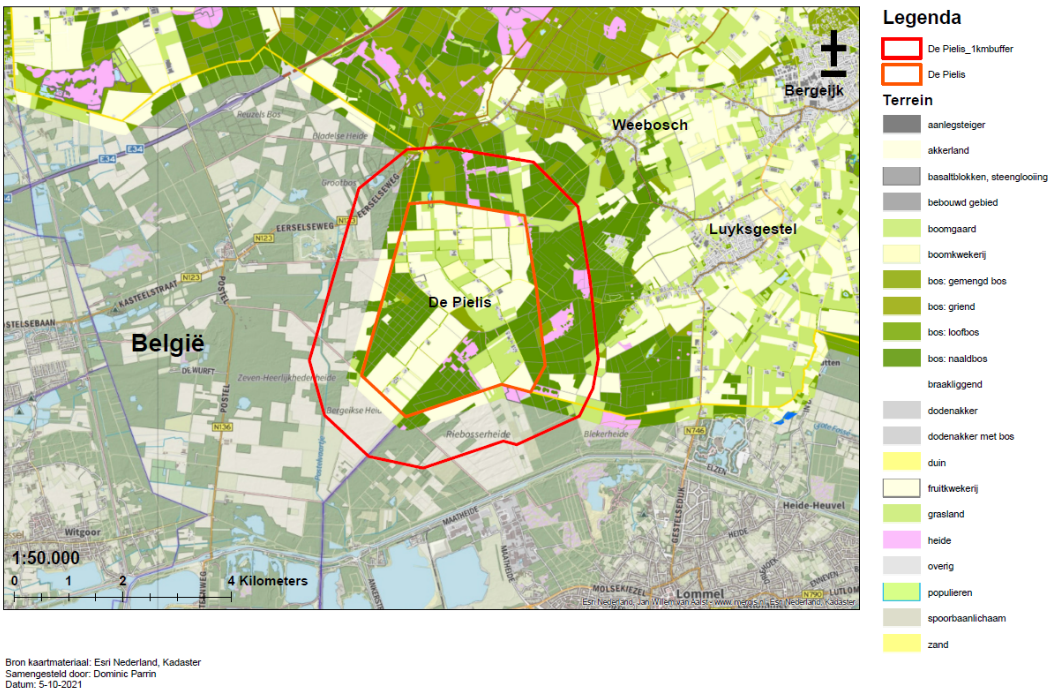
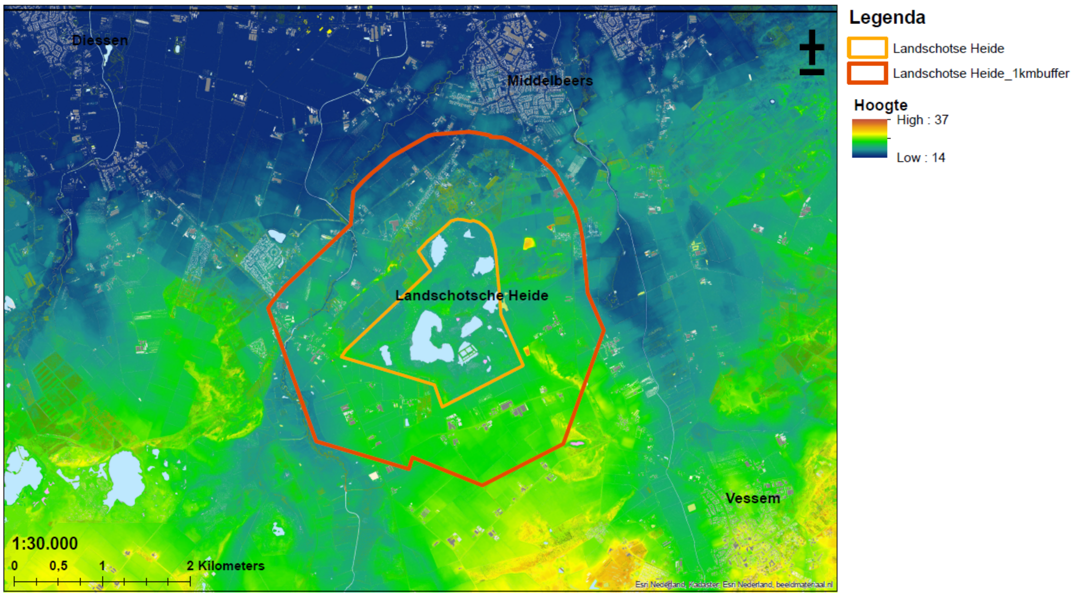


Figure 3.2: Topography of De Pielis area and its surrounding areas. The orange and red contours indicate the borders of De Pielis and a buffer of 1 km respectively.

lower, probably resulting in a northward outflow of water for the Landschotse Heide.

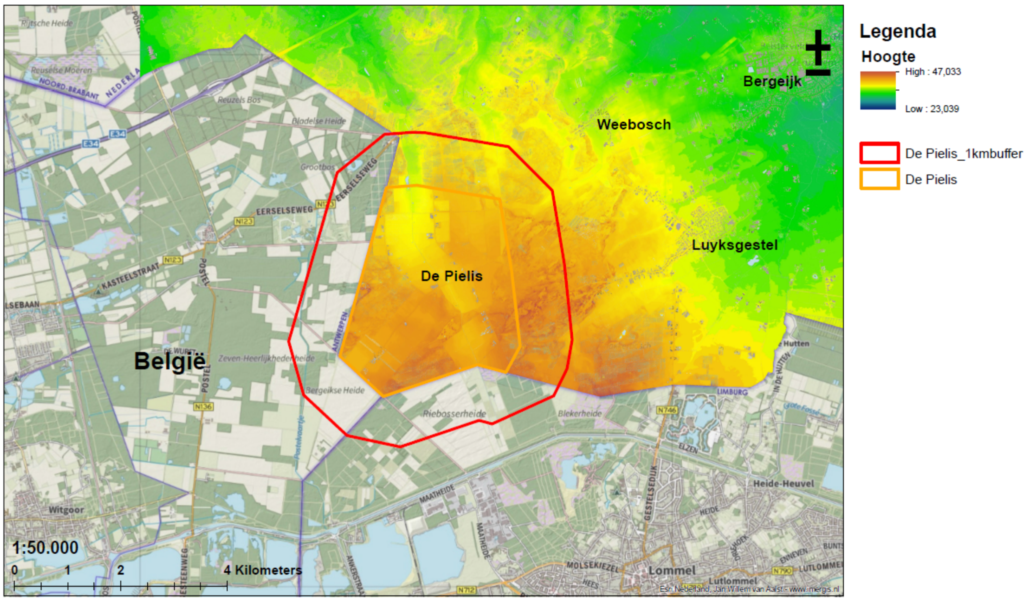


Bron kaartmateriaal: PDOK, Esri Nederland, beeldmateriaal.nl
Samengesteld door: Dominic Parrin
Datum: 5-10-2021

Figure 3.3: Elevation map of the Landschotsche Heide.

De Pielis

De Pielis area is one of the higher parts of De Dommel area (see Figure 3.4). North of the area the elevation is lower. Indicating a northward (ground)water flow as well.



Bron kaartmateriaal: PDOK, Esri Nederland, beeldmateriaal.nl
Samengesteld door: Dominic Parrin
Datum: 4-10-2021

Figure 3.4: Elevation map of De Pielis

3.3. History

The area of De Dommel used to contain large areas of heath-land and villages at various locations villages (Rijkswaterstaat, 2021 (map of 1872)). In these heath-land areas many fens could be found. Over the years most these heath-lands have been reclaimed for agriculture or urbanization.

Landschotse Heide

In 1925 the land around the Landschotse Heide consisted only of heath areas or forest areas (see Figure 3.5).

In 1937 it was decided that the southern part of the heath land, about 500 ha of wet heath land, would be reclaimed. Only the Northern part, with a few fens, would remain. After the second world war, however, there was a new mayor who did not want to honour these agreements and wanted to reclaim the whole heath land. This resulted in a diplomatic offensive from 'het Brabants Landschap', the local nature conservation organisation, which made sure the municipality could not reclaim any land at all. At last, in the 60's, the southern part of the heath land could be reclaimed (Visitoirschot, 2021).

Figure 3.1 shows that the area around the Landschotse Heide has changed to farmland (agriculture, orchard or grassland).

In 1999 the Landschotse Heide has been handed over to 'het Brabants Landschap' (Visitoirschot, 2021).

In 2016 some effort was taken to deepen the fens and reshape the area, but still no significant changes in wetness have been observed (Eindhovensdagblad, 2020). This project was finished in March of 2017 (landschap, 2017), but in 2020 nature enthousiasts wrote an urgent letter to the Water Board, the province, Brabants Landschap and the municipalities of Oirschot and Eersel. The message of the letter is that the area is still drying up (Today, 2021). According to Frans van Hoof, a member of 'Werkgroep Natuur en Landschap de Beerzen', the water table has lowered about 2 meters in the past 8 years. This results in tumbling firs and grassing of the fens (Eindhovensdagblad, 2020). The changes due to the project in 2016 would result in reaching the goals of Natura-2000 (Dommel, 2021).

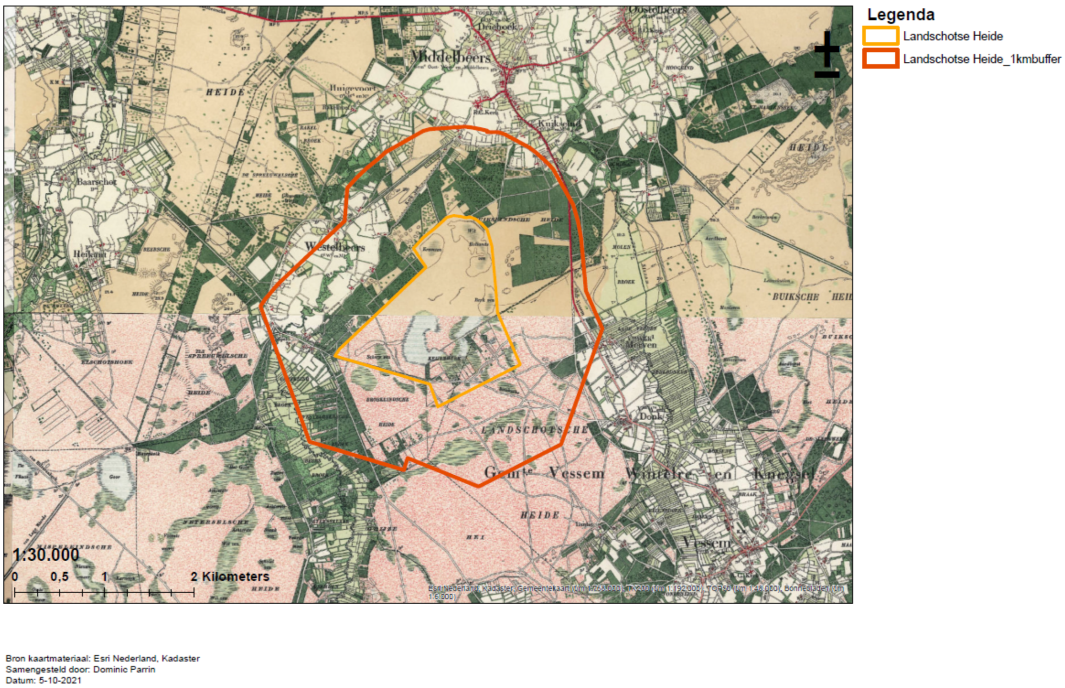


Figure 3.5: Topography of Landschotse Heide in 1925, most of the area is covered by heath (pink and orange surfaces). Dark green is forest area, light green is brook swamp and white is residential area.

De Pielis

In 1925 the biggest part of De Pielis area was covered with heath (see Figure 3.6). This area had been left to nature for a long time (Plaatsengids, 2020).

After the second world war more than half of the area was transformed to farmland by reclamation. The reclamation started in 1952 and ended in 1959. At this moment the second generation of farmers cultivate this land. Farmers describe this area as a sieve, water just runs through (Eindhovensdagblad, 2008).

In 2005 Water Board De Dommel constructed a fen, the Blauwe Knoop, at the most upstream part of the Goorloop in De Pielis (Eindhovensdagblad, 2008). The Goorloop springs a bit more upstream in Belgium. Downstream of De Pielis the Goorloop flows into the Aa stream which flows into the Grote Beerse more downstream. De Pielis can therefore be called the source area of the Grote Beerse.

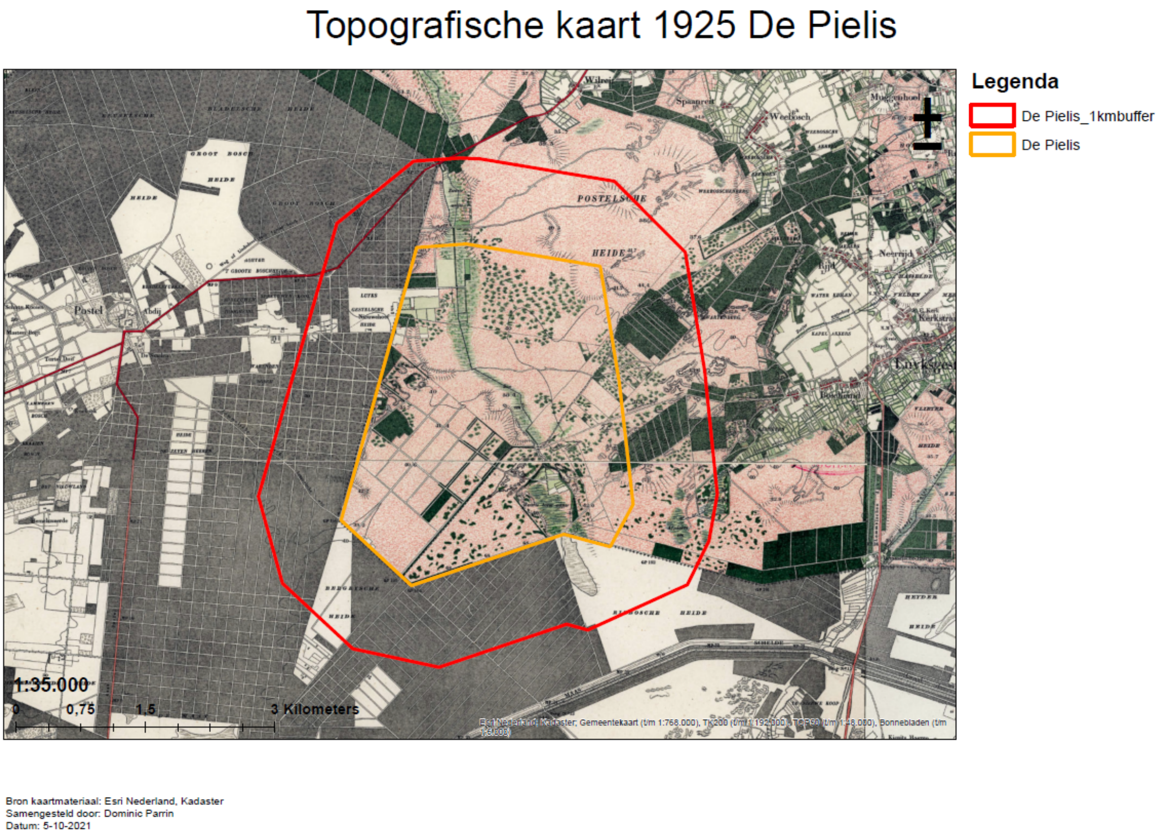


Figure 3.6: Topography of De Pielis in 1925, most of the area is covered by heath (pink areas). Dark green is forest area, light green is brook swamp and white is residential area.

In 2010 a plan was made to make the Goorloop an ecological connection zone (IVN, 2010). This connection zone should connect different nature areas to increase the habitat of different flora and fauna.

In 2017 is was decided that more fens and weirs are needed in the area and the Goorloop should get more room to meander. This will result in even more nature and water retention (Eindhovensdagblad, 2008).

3.4. Land use

The area of De Dommel is mostly used for agriculture and urbanised areas. The most common uses for agriculture are grassland, corn and potatoes (Alterra, 2018). In between the agricultural areas some nature can still be found. This is mostly heath-land or coniferous forest. The heath-land however do not have as many fens as they used to and have grassed.

Landschotse Heide

A quarter of the area of the Landschotse Heide used to be surface water. This gives a place to nest for ducks and grebes. In summer times the Spoonbill and the Black stork can be spotted. During Atumn large amounts of waders (like the Common greenshank, Spotted redshank and the Eurasian whimbrel) are located at the dried up banks (places, 2020). Also the Moor frog can be found at the Landschotse Heide.

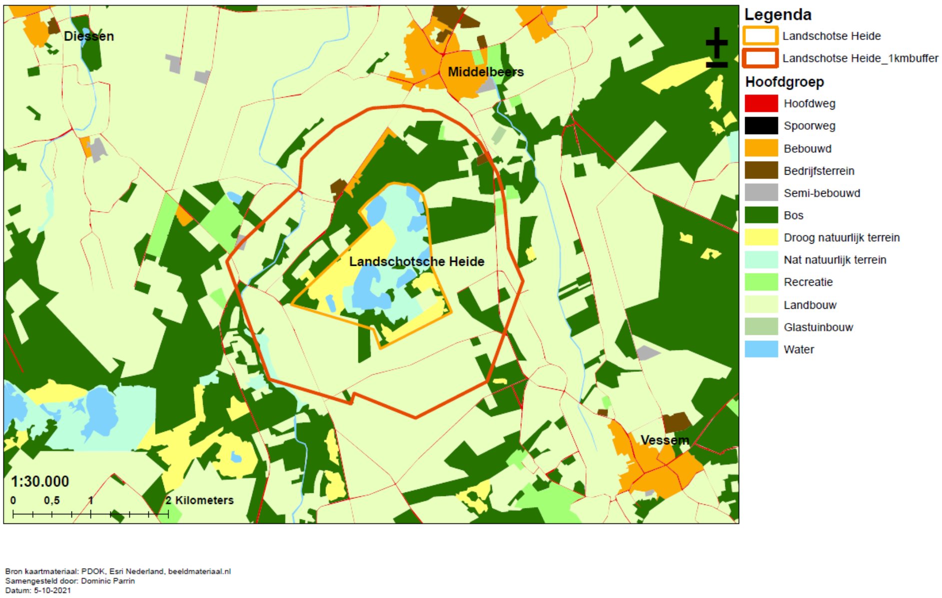


Figure 3.7: Land use in the Landschotse Heide area. Where yellow is dry natural area, Dark green is forest, mint is wet natural area and light green is agriculture.

Around the Landschotse Heide there is still some coniferous forest (Alterra, 2018). It is known that, on a yearly basis, coniferous trees use more water than deciduous trees or heath-land (Kang et al., 2009) (Swift Jr. et al., 1975). Figure 3.7 shows that most of the surrounding area of the Landschotse Heide consists of agriculture (marked as 'landbouw' in the figure).

De Pielis

After the reclamation the land of De Pielis has been used for agriculture (see Figure 3.8). In 2018 this consisted mostly of grassland, corn, potato's and cereals (Alterra, 2018).

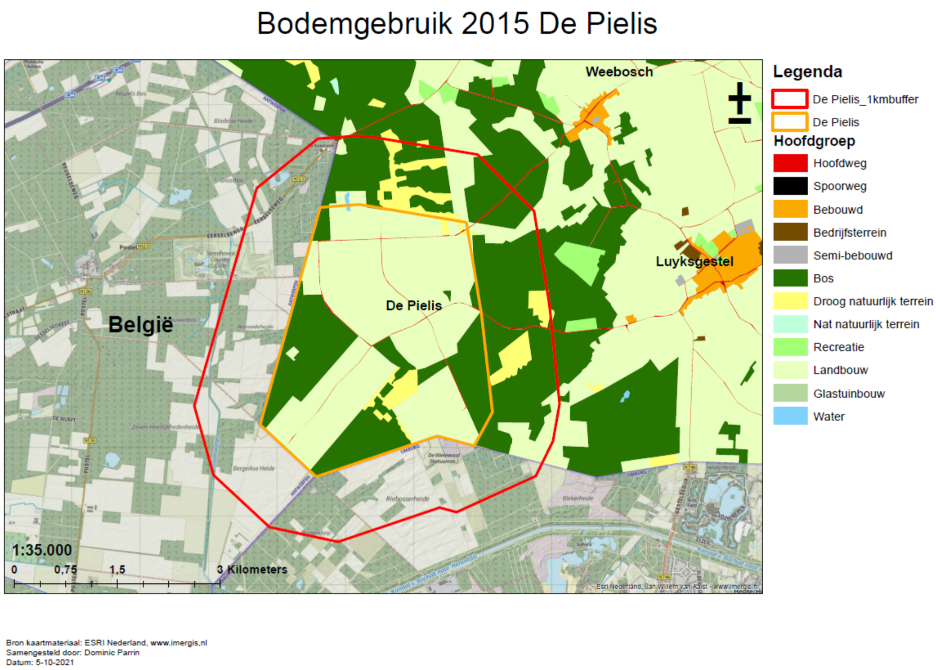


Figure 3.8: Land use in De Pielis area. Where light green is agriculture, Dark green is forest and yellow is dry nature.

3.5. Water management

Water Board De Dommel controls about 30.000 km watercourses. In these watercourses they control 1.774 weirs (Dommel, 2022a). In the appendix a picture of one of these weirs is shown.

Landschotse Heide

Figure 3.9 shows the watercourses in and around the area of the Landschotse Heide. Within this area there are no watercourses. Around it there are some A-watercourses with the purpose of draining the area for the farmland. Within the Landschotse Heide the surface water is only the fens. Although these fens are visible on the map, they are often dry. (For an impression of the area see the appendix as well as the cover image of this report.)

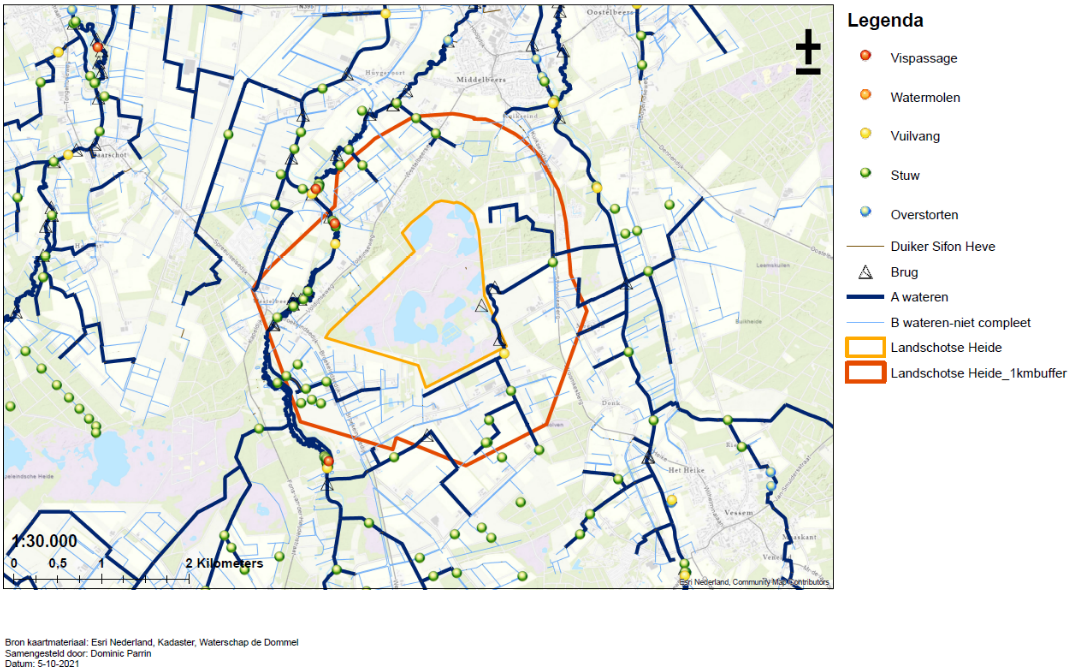


Figure 3.9: Watercourses in and around the area of the Landschotse Heide. Dark blue lines are the A-watercourses, light blue lines the (incomplete) B-watercourses, green dots the weirs and black lines the culverts.

In figure 3.10 it can be seen that the head of the Berkven has changed for the last three years. It can be seen that the fen is dry for longer periods (the straight lines) (Dommel, 2022b).

De Pielis

Within De Pielis area there is only one A-watercourse, the Goorloop. As mentioned above this watercourse springs just outside the Netherlands in Belgium. There are some small B-watercourses with the purpose of draining the farmland into the Goorloop. Figure 3.11 shows where these watercourses are located. This figure also shows the location of the weirs and culverts. As can be seen, there are four weirs located in the Goorloop within 700-800 meters. This is due to the slope op the Goorloop. Without these weirs the water would flow away to quickly downstream. In the appendix some pictures of the Goorloop and a B-watercourse are included to give an impression of the size of the watercourses.

In figure 3.12 the head of an upstream location (see Figure 3.13) in De Pielis is shown for the last four decades (Dommel, 2022b). As can be seen the groundwater level has decreased over the last 3 decades.

3.6. Geo(hydro)logy

Brabant has four types of geohydrological areas (see Figure 3.14): I. Westerly North-Brabant, II. Kempish Plateau, III. Central Rift Valley and, IV. Peelhorst-Venlo Rift Valley. The Feldbiss rift cuts through the area of De Dommel deviding the area on the Kempish Plateau and the Central Rift Valley.

Figure 3.10: Head of the Berkven from 2014 till 2020

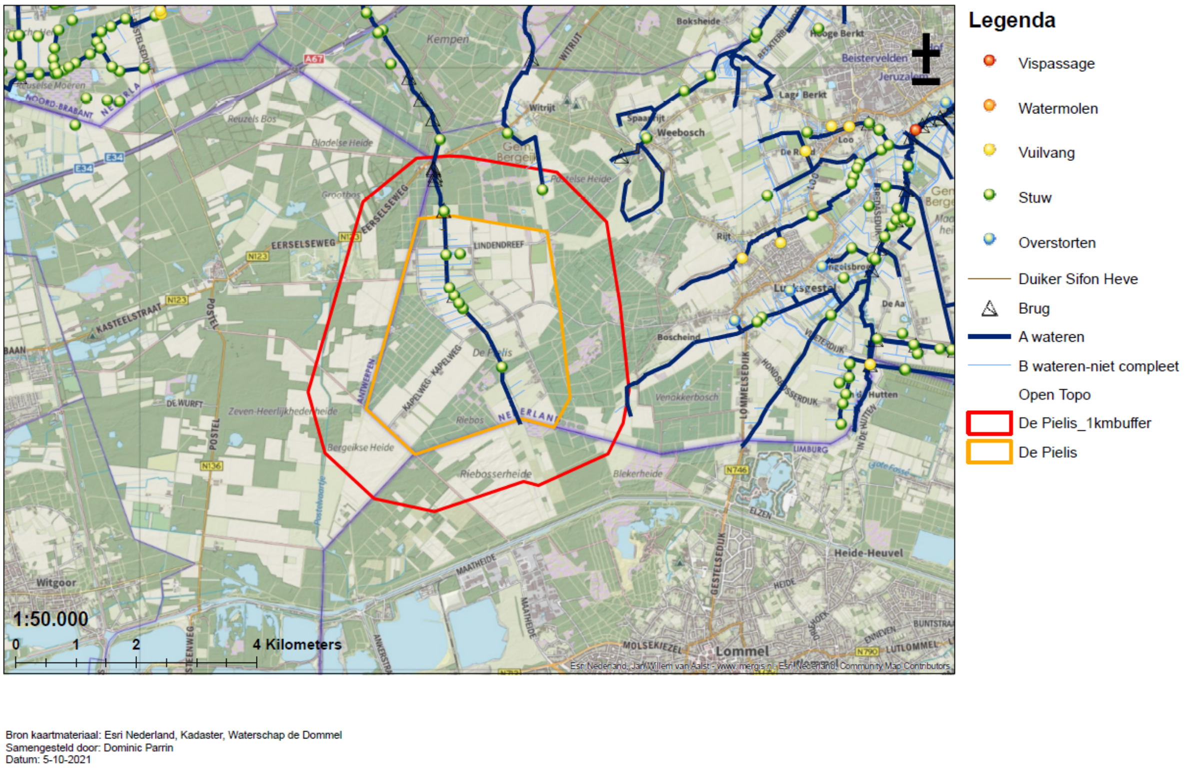


Figure 3.11: Watercourses in and around the area of De Pielis. Dark blue are the A-watercourses, light blue the (incomplete) B-watercourses, green dot the weirs and black lines the cluverts.

In the Kempish Plateau the high sandy and gravel soils are positioned on top of a thick clay layer (Waalre and Stramproy). These clay layers are at a lower elevation than the clay layers in West-Brabant. At most locations on top of the sand and gravel layers a layer with cover sand can be found. Locally it is possible to find the more course sand and gravel as the top layer. At these locations there is hardly and organic material available in the soil. Also the groundwater is very sensitive to pollution and acidification.(Noord-Brabant et al., 2007)

Within the Kemish Plateau there are two subdivisions (see Figure 3.15). The first profile has a small top layer of fine sediments with a thick sand layer as second layer. It is closed of at the bottom with a clay layer at great depth.

The second profile has a sand layer as top layer, a clay layer as second layer, followed by another sand

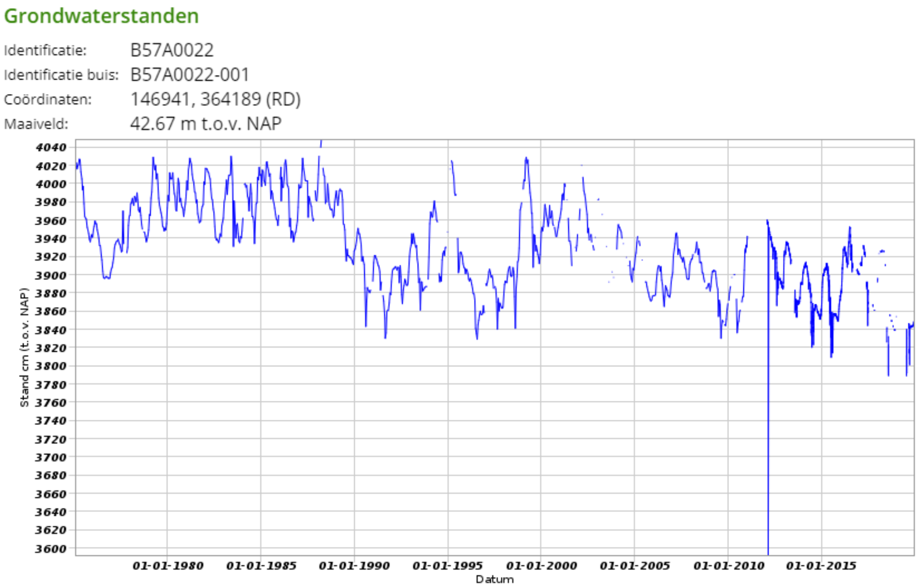


Figure 3.12: Head of a location in De Pielis for the last four decades

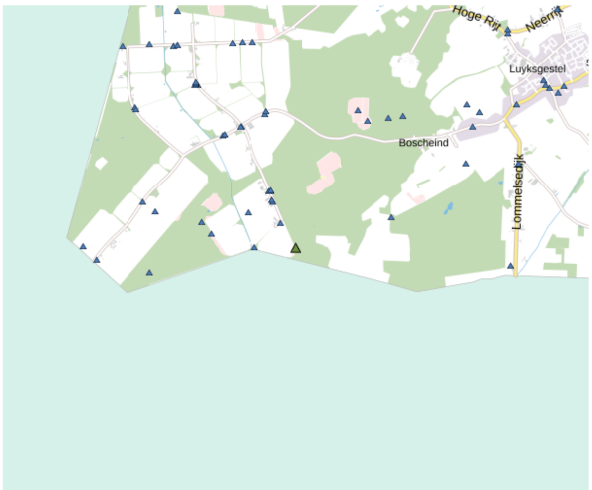


Figure 3.13: Location of head measurement in De Pielis (The bigger triangle at the south border)

layer and is closed off by a layer of fine sediments.

In the Central Rift Valley there are thick aquifers that reach up to Köln. The Boomse Clay is positioned at great depths, around Boxtel the top of this layer is at 1800 meters depth. The characteristic of the Central Rift Valley is the big groundwater systems. Besides that the geohydrological situation is very complex (Noord-Brabant et al., 2007).

As can be seen in Figure 3.15, there are also different profiles within the Central Rift Valley. It is clearly visible that in the Central Rift Valley the profiles have more diversity, more variations in soil layers.

Landschotse Heide

The Landschotse Heide is located on the Feldbliss rift and is therefore located on top of the two geohydrological areas.

At the south-west the Landschotse Heide is located on the Kempish Plateau. There it has the second profile for this area as shown in Figure 3.15. The first clay layer can therefore be found relatively high.

At the North-east, the Landschotse Heide is located on the Central Rift Valley. There the soil has a 3b profile as indicated in Figure 3.15. The top layer is a loamy layer followed by a sand layer. This sand layer is

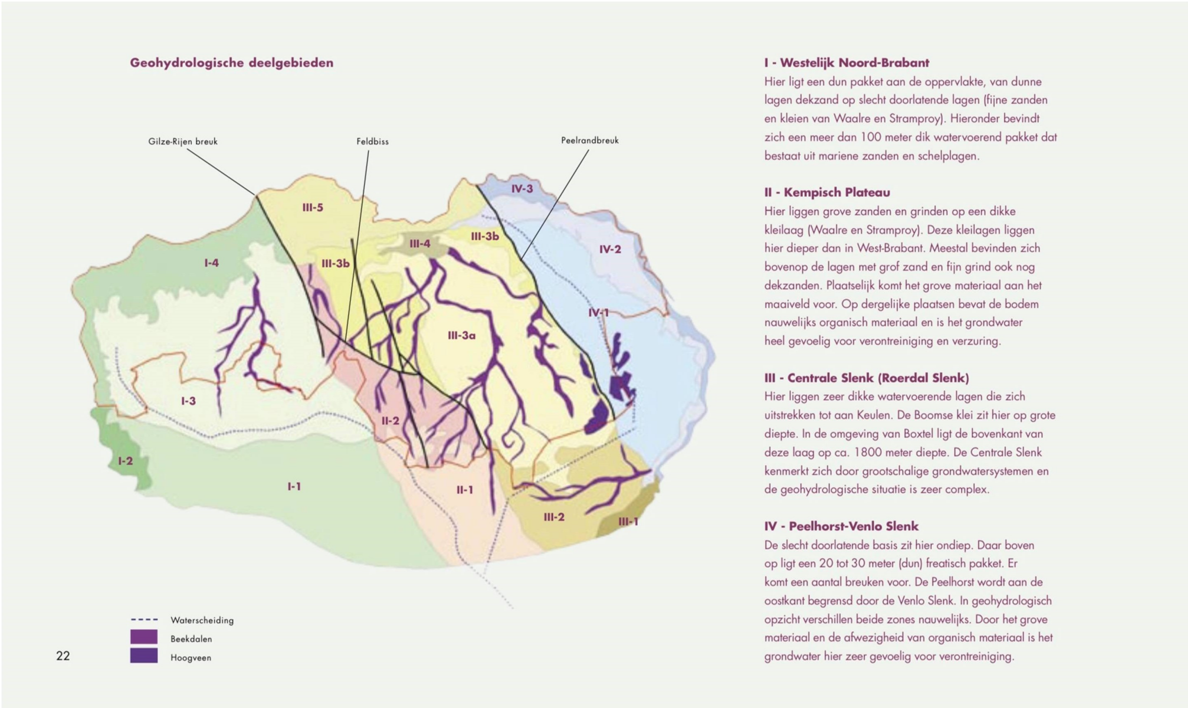


Figure 3.14: Geohydrological areas is and around Brabant. The orange line is the border of the province Brabant. (, p.22, Brabant Waterland)

followed by a few layers of clay and sand, alternately. The profile ends with a fine sediment layer. With this layering of sand and clay some aquifers have been formed. These are layers which can contain water because it is a permeable layer (sand) in between less permeable layers (clay/loam).

Figure 3.16 shows the soil profile of the Landschotse Heide for the transect shown in Figure 3.18. Figure 3.17 shows the top 60 meters of the soil profile of the Landschotse Heide. It clearly shows the layering of the sand and clay layers.

De Pielis

De Pielis is located at the Kempish Plateau with the first profile for this area as shown in Figure 3.15. This profile only has one clay layer, all the way at the bottom. This results in another groundwater behaviour. Groundwater can easily infiltrate to great depths.

Figure 3.19 shows the soil profile of De Pielis for the transect shown in Figure 3.21. Figure 3.20 shows the upper 25 meters of the soil profile of De Pielis. This clearly shows the height difference over the area and the slope of the stream valley towards the Goorloop (the low elevation in the middle of the transect).

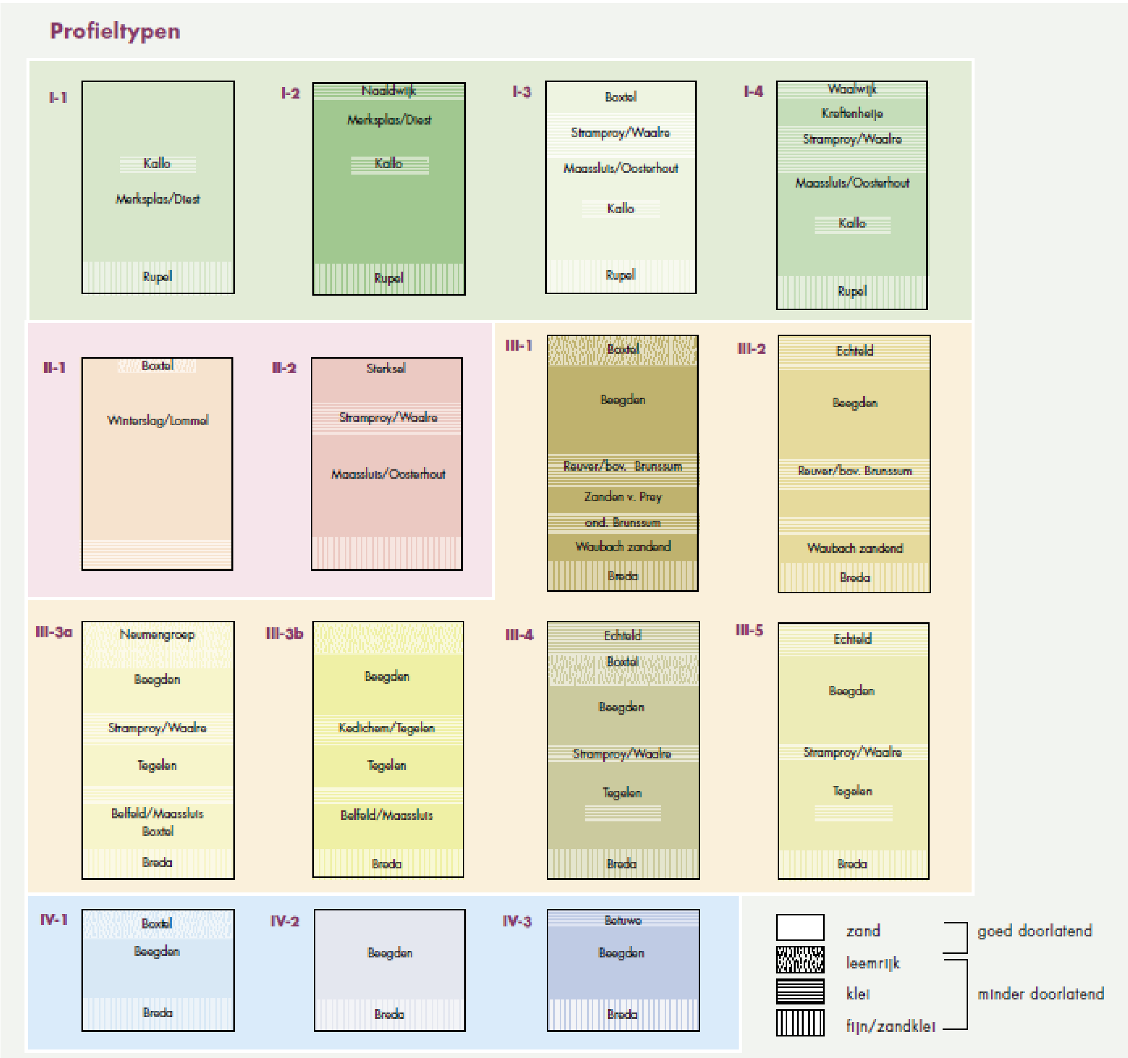


Figure 3.15: Profile types of the different geohydrological areas in Brabant. Zand=Sand, Leemrijk=Loamy, Klei=Clay, fijn/zandklei=Fine/Sandclay, goed doorlatend=high permeability and minder doorlatend=lower permeability. (, p.23, Brabant Waterland)

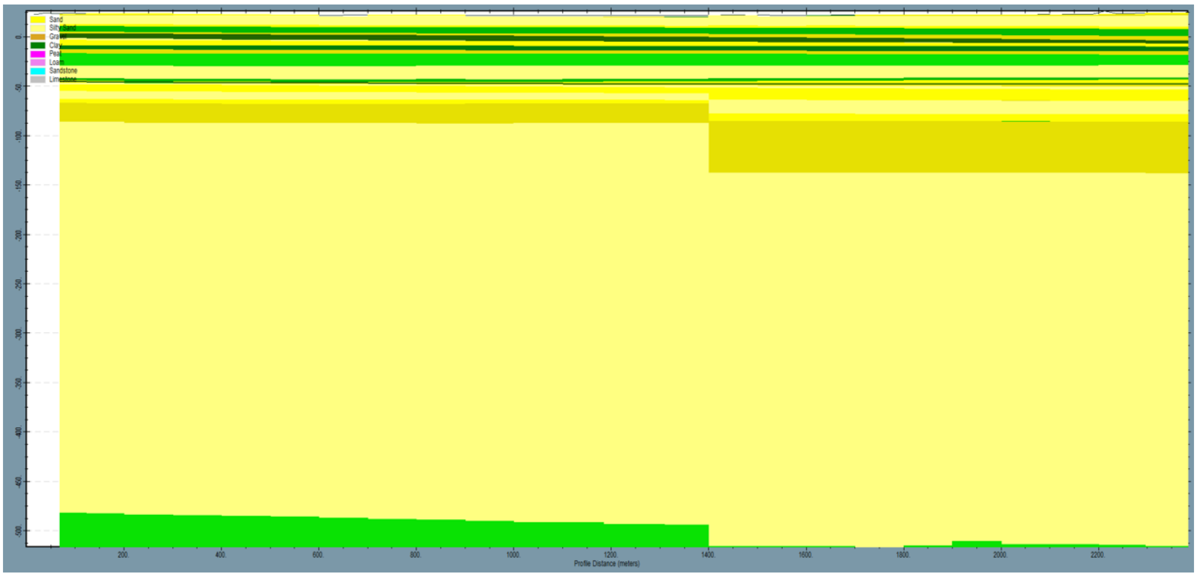


Figure 3.16: Soil profile of Landschotse Heide for the transect shown in Figure 3.18. Bright yellow=sand, light yellow=silty sand, light brown=gravel, green=clay, bright pink=peat, light pink=loam, blue=sandstone and gray=limestone.

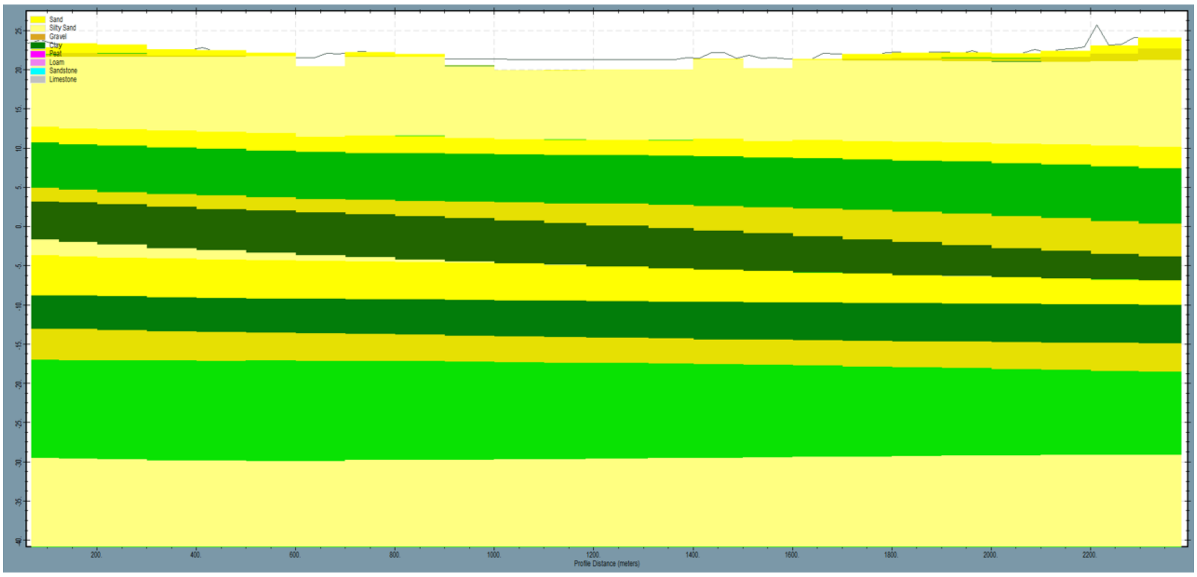


Figure 3.17: Soil profile of Figure 3.16, zoomed in to the upper 65 meters of Landschotse Heide. Bright yellow=sand, light yellow=silty sand, light brown=gravel, green=clay, bright pink=peat, light pink=loam, blue=sandstone and gray=limestone.

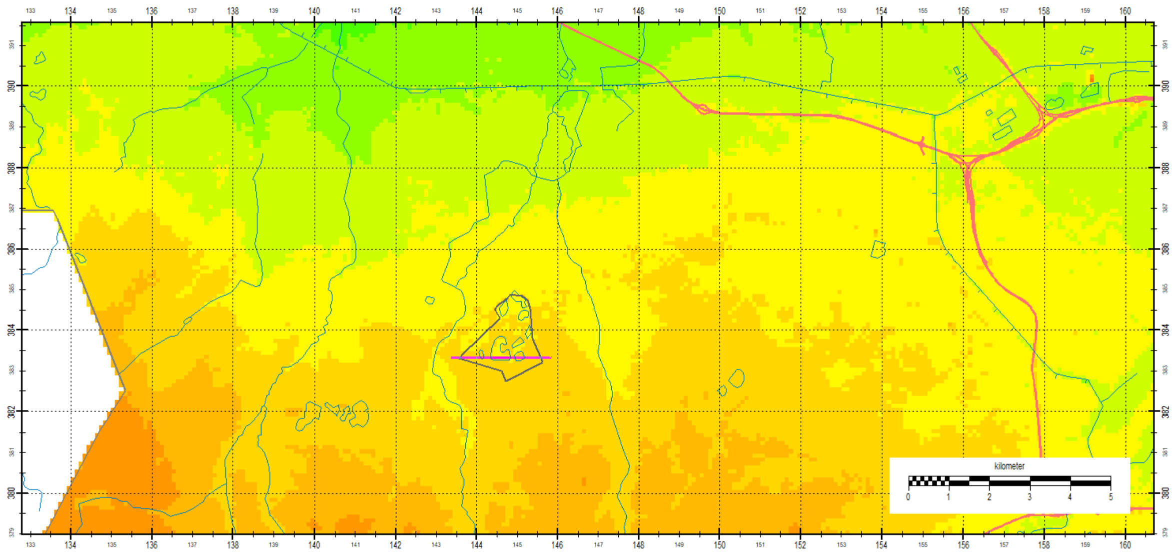


Figure 3.18: Transect of the Soil profile shown in Figure 3.16. The transect starts West of Landschotse Heide and ends East of Landschotse Heide (pink straight line in the middle).

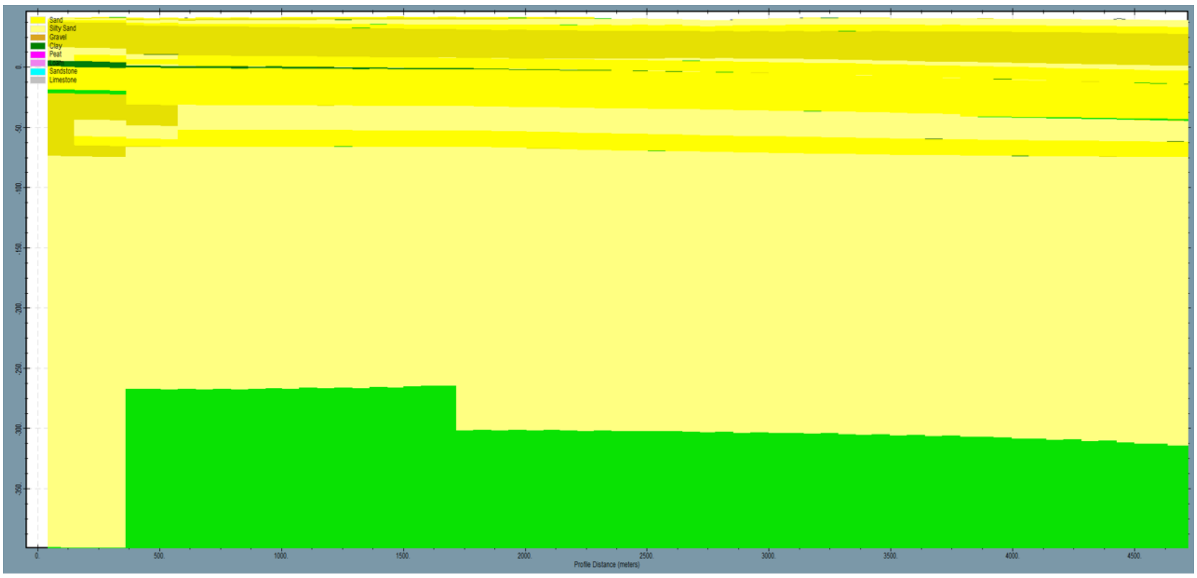


Figure 3.19: Soil profile of De Pielis for the transect shown in Figure 3.21. Bright yellow=sand, light yellow=silty sand, light brown=gravel, green=clay, bright pink=peat, light pink=loam, blue=sandstone and gray=limestone.

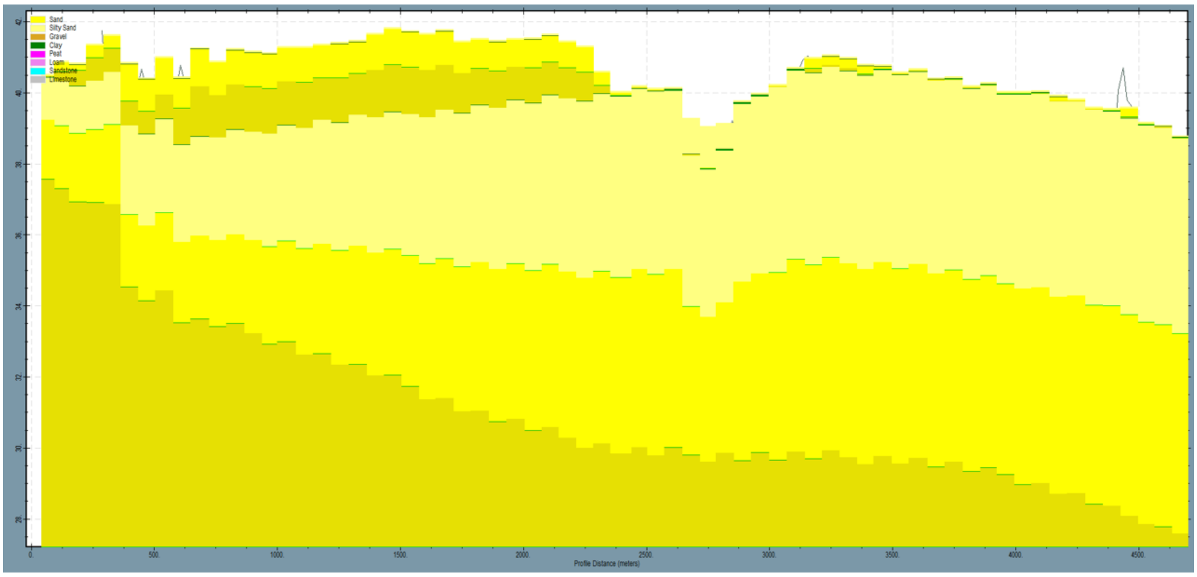


Figure 3.20: Soil profile of Figure 3.19, zoomed in to the upper 25 meters of De Pielis. Bright yellow=sand, light yellow=silty sand, light brown=gravel, green=clay, bright pink=peat, light pink=loam, blue=sandstone and gray=limestone.

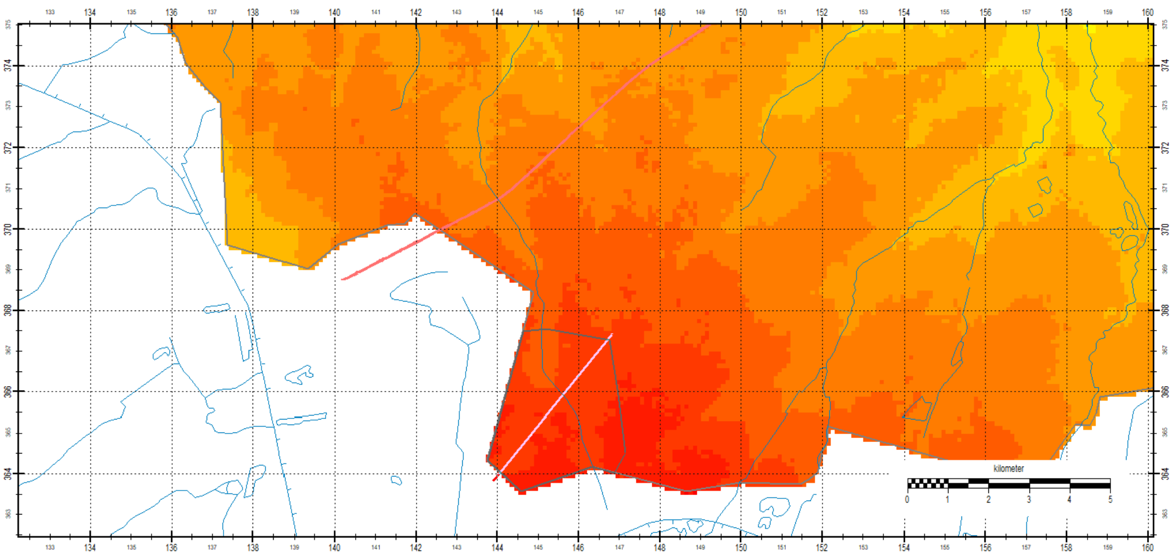


Figure 3.21: Transect of the Soil profile shown in Figure 3.19. The transect starts South-West of De Pielis and ends North-East of De Pielis (pink straight line in the lower middle).

4
Results

In this chapter the results of the model are shown combined with expert judgement. This chapter therefore show the signals as defined in Chapter 2 (M of XLRM framework). With these results the following sub research questions will be answered: 'How do the signals react to the interventions', 'What is the difference in the results of the interventions for both areas?' and 'How can this difference be explained?'. First the results of the BASE model will be showed to give a better understanding of the areas. The results of the BASE model also function as the reference data to compare the results of the interventions and scenarios to. The first results are the water balances for the first aquifer layer and the first four aquifer layers combined, for both research areas. After this the flow path are shown for two transects for both research areas.

After this the results of the different interventions, combined interventions and the scenarios modeled in the stationary model and their difference with the BASE model are shown. These results also include the head differences compared to the BASE model in the first aquifer layer.

Thereafter the results of the non-stationary models and their differences with the non-stationary BASE model are shown.

Lastly the differences between the results of the areas are described and analysed as well as the differences between the stationary and non-stationary model.

4.1. BASE model

This section gives a detailed analysis of the BASE model results. This helps us to understand how the groundwater model behaves and how the water related problems are represented in the model. It shows the water balances and the flow paths of the Landschotse Heide and De Pielis.

4.1.1. Water balance

Tables 4.1 and 4.2 show the water balances for 2018 of the Landschotse Heide and De Pielis respectively. They show the recharge (RCH), overland flow (OLF), drainage through B- and C-waterways (DRN), discharge through the A-waterways (RIV) and the flow through the right front (FRF), forward front (FFF) and bottom front (FBF).

In Table 4.1 it can be seen that, for the Landschotse Heide, most of the water in the first layer flows to the second layer (FLF) and a bit flows away through the A-waterways. When the top four layers are combined it can be seen that part of the water is converted horizontally (FRF and FFF), still quite some water leaves the fourth layer at the bottom (FLF) and the discharge through the A-waterways is about 1/3 of the total water flow.

Table 4.2 shows, for De Pielis, that almost all the recharge (RCH) that falls onto the first layer flows to the second layer (FLF). When the top four layers are combined still the biggest part of the water is flowing downward (FLF) and only a small part is flowing out of the area by river discharge (RIV and DRN) or by horizontal flow (FRF and FFF).

Table 4.1: Water balance of 2018 for the Landschotsche Heide for layer 1 (left part) and for the first 4 layers combined (right part), where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	layer 1			layers 1-4		
post	IN (mm)	OUT (mm)	SUM (mm)	IN (mm)	OUT (mm)	SUM (mm)
RCH	295	0	295	295	0	295
OLF	0	0	0	0	0	0
DRN	0	-1	-1	0	-8	-8
RIV	0	-25	-25	0	-104	-104
FRF	0	0	0	15	-28	-12
FFF	0	0	0	30	-89	-59
FLF	15	284	269	29	-140	-111

Table 4.2: Water balance of 2018 for De Pielis for layer 1 (left part) and for the first 4 layers combined (right part), where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	layer 1			layers 1-4		
post	IN (mm)	OUT (mm)	SUM (mm)	IN (mm)	OUT (mm)	SUM (mm)
RCH	354	0	354	354	0	354
OLF	0	0	0	0	0	0
DRN	0	-1	-1	0	-7	-7
RIV	0	0	0	0	-28	-28
FRF	0	0	0	0	-8	-8
FFF	0	0	0	2	-17	-14
FLF	1	-353	-352	22	-319	-297

4.1.2. Flow paths

Figures 4.1 and 4.4 show the top view of the flow paths for the starting point in and surrounding the Landschotse Heide and De Pielis respectively. Figures 4.3a, 4.3c, 4.6a and 4.6c show these flow paths from a side view.

Figure 4.1 shows that the water in the top aquifer layer in and around the Landschotse Heide mostly flows towards the North. Figure 4.3a shows this northward flow from a side view. Figure 4.3b is zoomed in to the upper 60 m of this side view. It can be seen that at the North side (downstream) of the fault (right in the figure) the groundwater is able to seep through the aquitard located around 0 $mNAP$. This means that the groundwater is able to flow to lower aquifer layers. At the South side (upstream) of the fault (left in the figure) there is some upward seepage visible but there is no infiltration through the aquitard layer. This small amount of seepage is also visible in Figures 4.3c and 4.3d as well as a bit of infiltration. These figures show the flow paths for a West-East transect, South of the fault (see Figure 4.2b for the location of the transect). There are only a few flow paths visible in this figure, indicating that the primary flow is in the perpendicular direction (South or North wards). This figure also shows that the groundwater at this side of the fault does not reach the deep sand layers but only to -40 $mNAP$. Figure 4.3a shows that on the downstream side of the fault the groundwater reaches a depth of almost -200 $mNAP$.

Figure 4.3d clearly shows that the Landschotse Heide is located on a watershed. Part of the flow paths flow towards the West (left) and part flow towards the East (right). At the West side most flow paths end in the Grote Beerze (Blue dots) which will discharge the water to downstream areas. This also means that there is almost no water flowing into the area from the East or West.

As can be seen in Figure 4.4, many flow paths for the starting points in and surrounding De Pielis end at the model border (blue lines at the North and South-West). This water will not stop flowing at that point but continue to flow more Northward (top of figure) or South-Westward (lower left corner). Because De Pielis is located at the highest part in the surroundings, it is also located at a watershed. Figures 4.6a and 4.6c show this as well. Especially for the West-East transect it shows a clear division of the flow paths to the East and

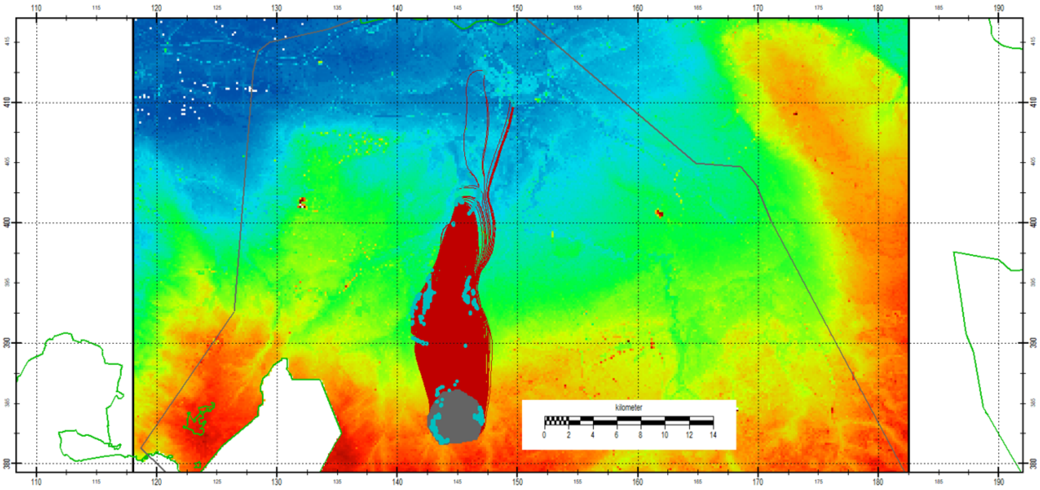
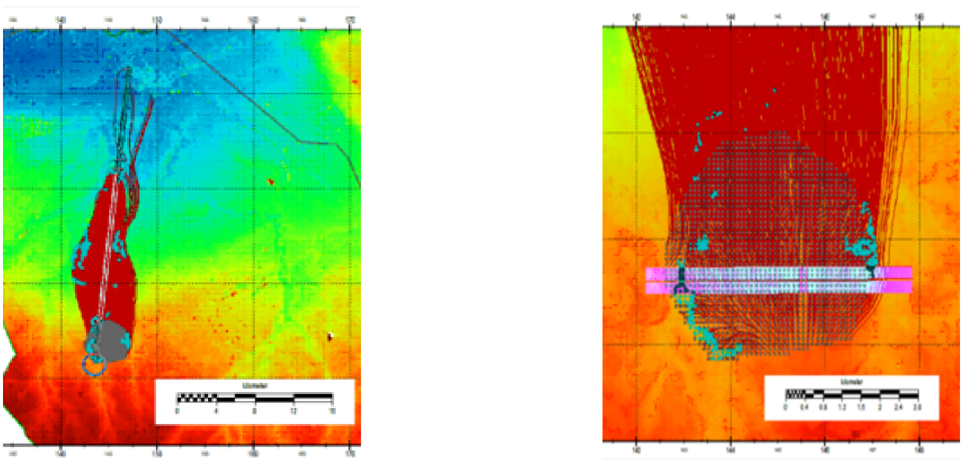


Figure 4.1: Top view of the flow paths of starting points in and around the Landschotse Heide, where gray are the starting points, red are the flow paths and blue are the end points of the flow paths.



(a) Transect of the shown flow paths in Figures 4.3a and 4.3b. The white line shows the South-North transect.

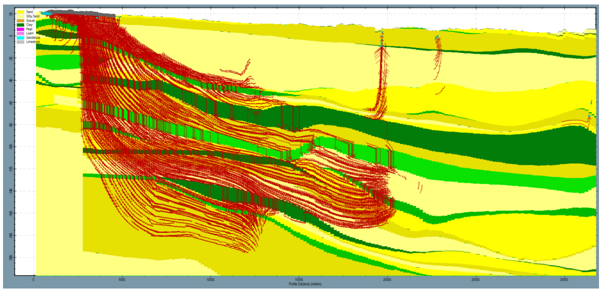
(b) Transect of the shown flow paths in Figures 4.3c and 4.3d. The thick pink line shows the West-East transect.

Figure 4.2: Transects of the flow paths for the Landschotse Heide

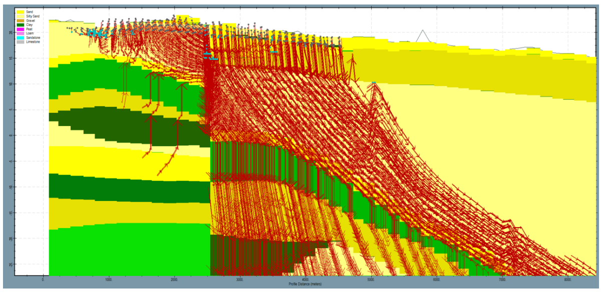
West.

Figures 4.6a and 4.6b show the South-North side view of the flow paths for the starting points in and surrounding De Pielis. The flow paths show that water from the top aquifer in De Pielis flows down to great depths. In Figure 4.6b it can be seen that the water flows to at least 100 meters depth (-60 $mNAP$). It is also clear that De Pielis is located on a thick sand soil (yellow layers) and that the aquitards (green layers) are only thin layers and not continuous through the whole transect, making it easy for the groundwater to infiltrate to the bottom of the lowest sand layer at a depth of -300 $mNAP$.

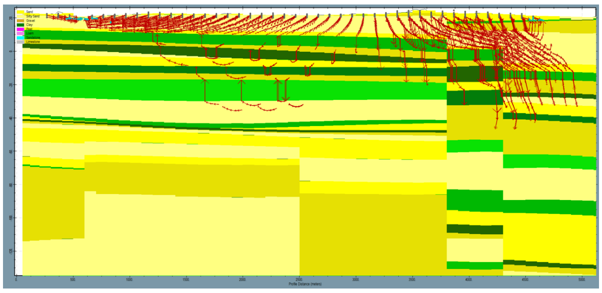
Figure 4.6d shows that some flow paths end as seepage West of De Pielis, this is outside the border of the Netherlands. So water that falls as rain in the Netherlands ends up in Belgium via the soil.



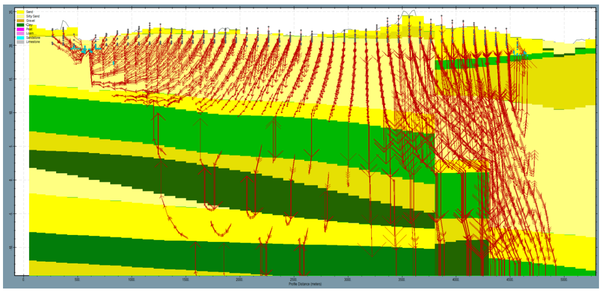
(a) South-North transect



(b) Zoom of top layers South-North transect



(c) West-East transect



(d) Zoom of top layers West-East transect

Figure 4.3: Side view of the flow paths for the Landschotse Heide for the transects shown in Figure 4.2b, where the gray dots are the starting points, the red lines are the flow paths, the blue dots are the end points of the flow paths, yellow areas are aquifers and green areas are aquitards.

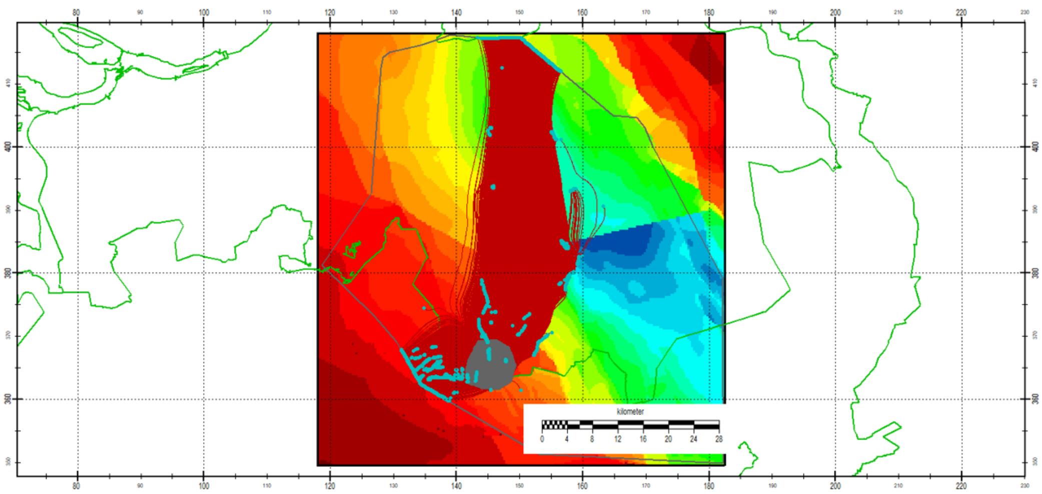
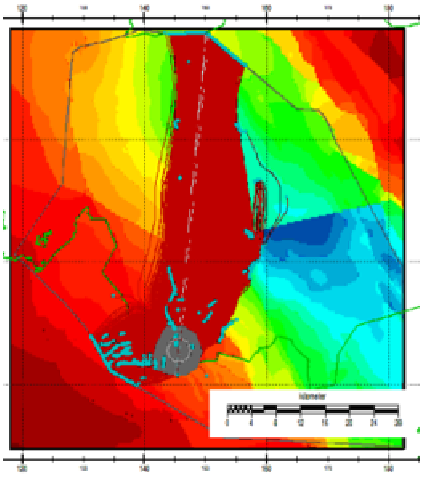
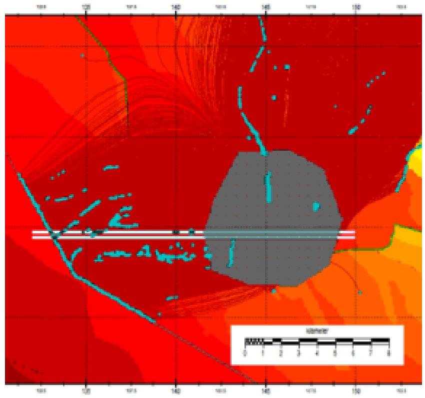


Figure 4.4: Top view of the flow paths of starting points in and around De Pielis, where the gray dots are the starting points, the red lines are the flow paths and the blue dots are the end points of the flow paths.

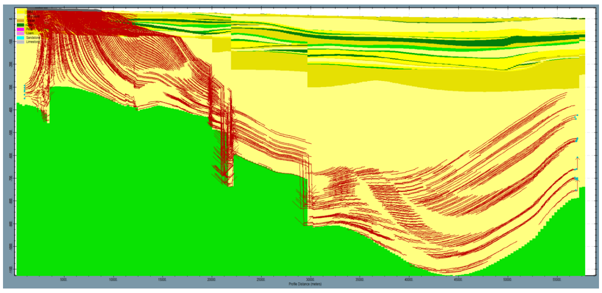


(a) Transect of the shown flow paths in Figures 4.6a and 4.6b. The white line shows the North-South transect.

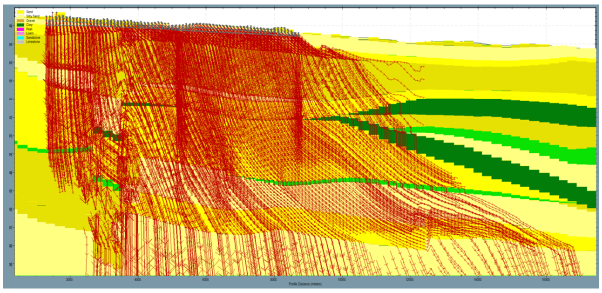


(b) Transect of the shown flow paths in Figures 4.6c and 4.6d. The white line shows the West-East transect.

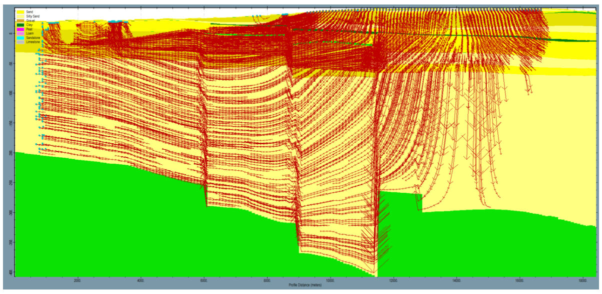
Figure 4.5: Transects of the flow paths for De Pielis



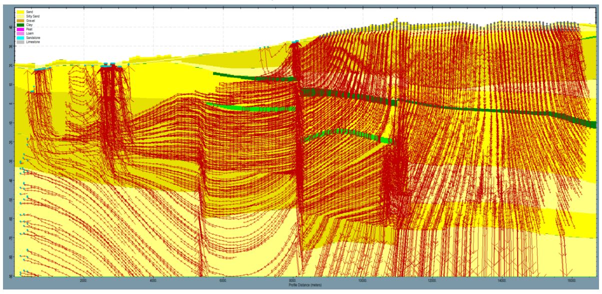
(a) South-North transect



(b) Zoom of top layers South-North transect



(c) West-East transect



(d) Zoom of top layers West-East transect

Figure 4.6: Side view of the flow paths for De Pielis for the transects shown in Figure 4.5, where the gray dots are the starting points, the red lines are the flow paths, the blue dots are the end points of the flow paths, yellow areas are aquifers and green areas are aquitards.

4.2. Single interventions

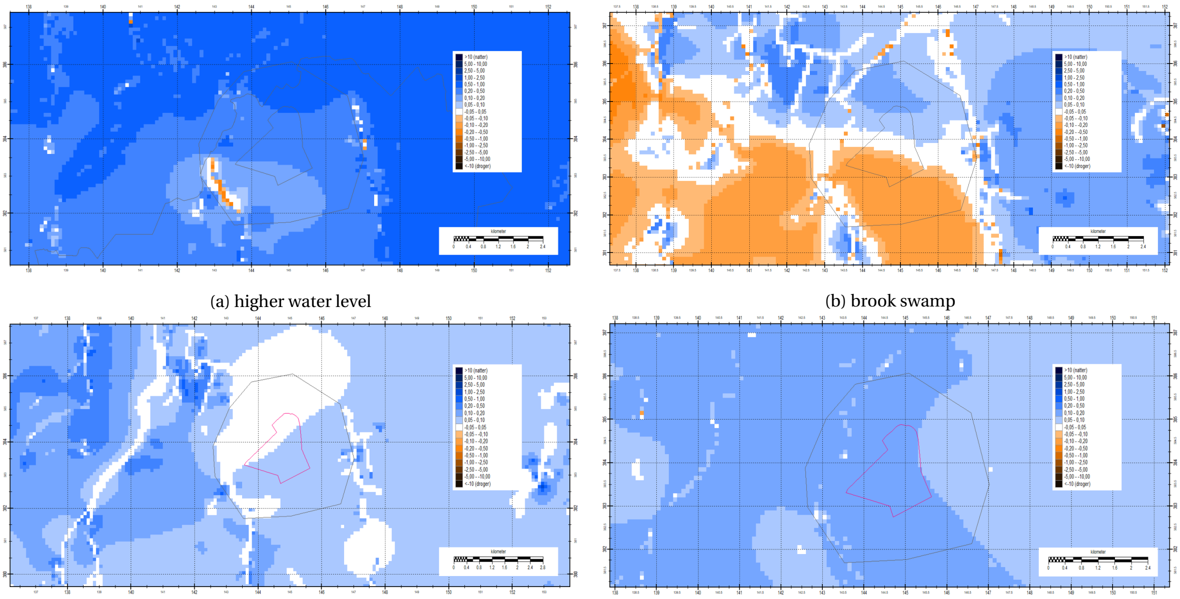
In this section the results of the single interventions and the difference between the single interventions and the BASE model are shown. Because not all interventions are as promising, only the results of the most promising or remarkable interventions are shown. All interventions are also ran for the four climate scenarios mentioned in Chapter 2 (X of XLRM). The results that are not included in this chapter can be found in the Appendix.

4.2.1. Head

In this subsection the head differences for the single interventions compared to the BASE model are shown for the Landschotse Heide and De Pielis. Only four of the interventions are discussed in this section: the "higher water level", the "Brook swamp", the "Closed ditches" and the "Less mowing" interventions. The legend shows the head differences in meters per year.

Landschotse Heide

For the Landschotse Heide several interventions seem promising when looking at the head maps. Especially a "higher water level" in the waterways gives quite an increase in the head for the first aquifer layer (see Figure 4.7a). The orange strip, indicating that it will become dryer at that location, might have to do with the water level of the Grote Beerze which is located there. It might be that the water level of the Grote Beerze at that location is higher in the BASE model than it is in the intervention. In the intervention the water level is placed 0.4 m below ground level.



(a) higher water level (b) brook swamp

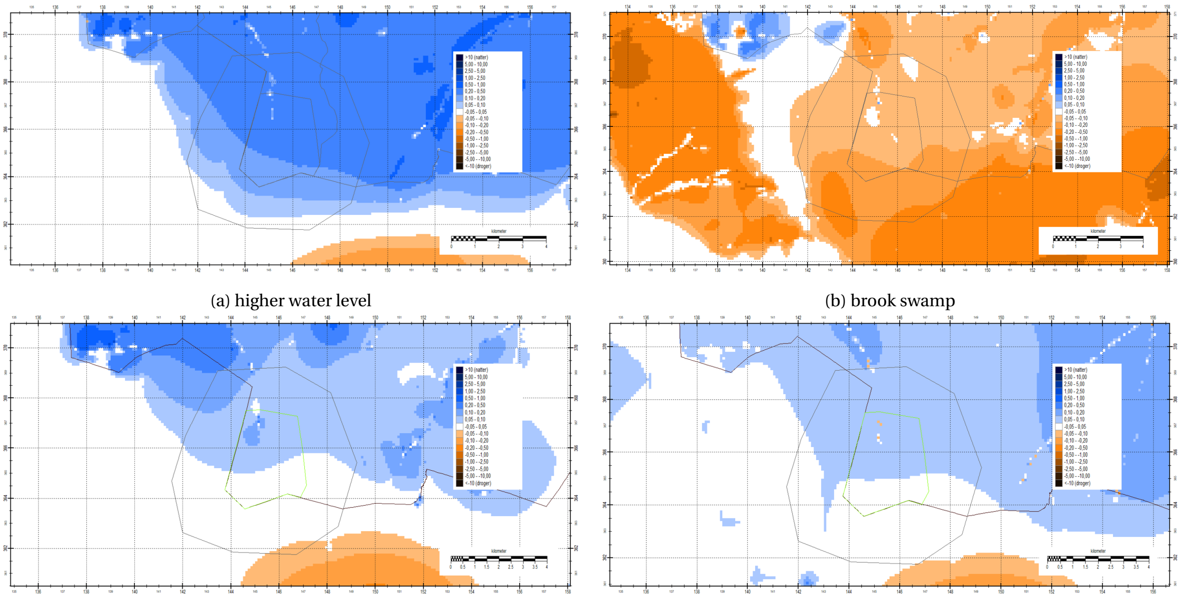
(c) closed ditches (d) less mowing

Figure 4.7: Head difference for the Landschotse Heide and its surroundings for the interventions (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

Figures 4.7b, 4.7c and 4.7d show the difference in head for the "brook swamp", "closed ditches" and "less mowing" interventions respectively. For the "brook swamp" intervention a clear difference is visible for both sides of the fault. At the South side of the fault it becomes dryer while at the north side it becomes wetter. This might mean that at the South side of the fault the "brook swamp" has a draining effect instead of an infiltrating effect. The head difference for the "closed ditches" intervention shows no change at the North side of the Landschotse Heide. The North-East area of this region is the fir forest area, where there are no B- or C-waterways. Also within the area of the Landschotse Heide itself there are no B- or C-waterways. This might be the reason for the white area North of the Landschotse Heide. The head difference for the "less mowing" intervention shows a small increase in wetness every where.

De Pielis

Also for De Pielis the most promising intervention when looking at the head is the "higher water level" intervention (see Figure 4.8a). Figure 4.8b shows an unexpected outcome. It shows that with the "brook swamp" intervention it becomes dryer at De Pielis. This might mean that the waterways in De Pielis have a high draining effect because even with an infiltration factor and wider waterways the area becomes dryer. This might be the result of the steep slope in this area. Figures 4.8c and 4.8d show the head differences for the "closed ditches" and "less mowing" interventions respectively. They both show a small positive result for the South part of De Pielis.



(a) higher water level

(b) brook swamp

(c) closed ditches

(d) less mowing.

Figure 4.8: Head difference for De Pielis and its surroundings for the interventions (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

4.2.2. Water balance

In this subsection the water balance for the BASE model and the interventions discussed above are shown, compared and analysed for the Landschotse Heide and De Pielis.

Landschotse Heide

The water balances for the Landschotse Heide and the different interventions are shown below. Table 4.5 shows the water balance for the BASE model, the "higher water level" intervention, the "brook swamp" intervention and the "closed ditches" intervention. Table 4.4 shows the water balance for the "agricultural abstraction" intervention and the "less mowing" intervention. Tables 4.5 and 4.6 show the water balances for the top four aquifer layers combined for the BASE model and the same interventions.

When looking at the first aquifer layer for the Landschotse Heide it can be seen that the "higher water level" intervention has the biggest increase in seepage to the first layer. This intervention is also the only intervention that results in more discharge in the B- and C-waterways. If this water can be captured in these waterways preventing it to flow downstream, even more water will be able to infiltrate into the top aquifer layers in the area. The second best option when looking at the first aquifer layers is the "brook swamp" intervention. This intervention results in almost a doubled seepage to the first aquifer layer and also more river outflow. The "agricultural abstraction" scenario results in less seepage to the first aquifer layer and more infiltration to the second aquifer layer, as expected. This is due to the increase of abstraction in lower aquifer layers resulting in more suction on the water in higher aquifer layers. The "closed ditches" and "less mowing" interventions only show small positive results. The "closed ditches" intervention is the only intervention with overland flow which might be a positive result when this overflow can be captured within the area, especially if this over land flow is flowing toward the fens.

Table 4.3: Water balance of 2018 for the first aquifer layer for the Landschotse Heide. It shows the water balance for the BASE model, the "higher water level", "brook swamp" and "closed ditches" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Higher water level			Brook swamp			Closed ditches		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0	0	-1	-1
DRN	0	-1	-1	0	-19	-19	0	-1	-1	0	0	0
RIV	0	-25	-25	0	-36	-36	1	-40	-40	0	-29	-29
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	15	-284	-267	39	-278	-240	27	-281	-254	18	-283	-265

Table 4.4: Water balance of 2018 for the first aquifer layer for the Landschotse Heide. It shows the water balance for the "agricultural abstraction" and "less mowing" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	Agricultural abstraction			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295
OLF	0	0	0	0	0	0
DRN	0	-1	-1	0	-2	-2
RIV	0	-22	-22	0	-27	-27
FRF	0	0	0	0	0	0
FFF	0	0	0	0	0	0
FLF	14	-286	-272	17	-283	-266

When looking at the top four aquifer layers combined for the Landschotse Heide it can be seen that also for this case the "higher water level" intervention has the biggest increase in seepage, this time to the fourth aquifer layer. It also results in more horizontal inflow and less horizontal outflow, keeping more water inside the area. The "closed ditches" intervention also has a big increase in seepage, but has less decrease in the infiltration to the fifth aquifer layer than the "higher water level" intervention. The "brook swamp" interventions shows a decrease in seepage to the fourth aquifer layer and an decrease in horizontal inflow. So when looking at these combined aquifer layers this intervention results in a dryer area than for the BASE model. This intervention however is the only intervention resulting in river inflow. The "agricultural abstraction" intervention results in more infiltration to the fifth aquifer layer due to the increase abstraction rate in lower aquifer layers. This also has an effect on the horizontal flow, which now becomes more vertical flow. The "less mowing" intervention only shows small differences.

Table 4.5: Water balance of 2018 for the top four aquifer layers combined for the Landschotse Heide. It shows the water balance for the BASE model, the "higher water level", "brook swamp" and "closed ditches" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Higher water level			Brook swamp			Closed ditches		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0	0	-1	-1
DRN	0	-8	-8	0	-22	-22	0	-3	-3	0	0	0
RIV	0	-104	-104	0	-122	-122	46	-135	-89	0	-122	-122
FRF	15	-28	-12	21	-22	-1	13	-27	-15	19	-27	-8
FFF	30	-89	-59	32	-82	-50	29	-90	-60	31	-89	-58
FLF	29	-140	-111	33	-133	-100	25	-153	-128	32	-138	-106

Table 4.6: Water balance of 2018 for the top four aquifer layers combined for the Landschotse Heide. It shows the water balance for the "agricultural abstraction" and "less mowing" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	Agricultural abstraction			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295
OLF	0	0	0	0	0	0
DRN	0	-7	-7	0	-9	-9
RIV	0	-88	-88	0	-102	-102
FRF	15	-24	-9	15	-28	-13
FFF	31	-24	-9	29	-89	-59
FLF	24	-163	-139	28	-140	-111

De Pielis

The water balances for De Pielis and the different interventions are shown below. Table 4.7 shows the water balance for the first aquifer for the BASE model, the "higher water level" intervention, the "brook swamp" intervention and the "closed ditches" intervention. Table 4.8 shows the water balance for the first aquifer for the "agricultural abstraction" intervention and the "less mowing" intervention. Tables 4.9 and 4.10 show the water balances for the top four aquifer layers combined for the BASE model and the same interventions.

When looking at the first aquifer layer it can be seen that also for De Pielis the "higher water level" intervention results in the biggest seepage increase. This intervention also results in an increase in the drainage and river outflow which, if captured, can be used to infiltrate more water inside the area. Also here the "closed ditches" intervention results in a small amount of over land flow. Especially in this steep area this over land flow show be captured to infiltrate within the area to have a positive effect. If it cannot be captured it will simply flow downstream. The other interventions show almost no changes.

Table 4.7: Water balance of 2018 for the first aquifer layer for De Pielis. It shows the water balance for the BASE model, the "higher water level", "brook swamp" and "closed ditches" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Higher water level			Brook swamp			Closed ditches		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0	0	-1	-1
DRN	0	-1	-1	0	-6	-6	0	-1	-1	0	0	0
RIV	0	0	0	0	-2	-2	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	1	-353	-353	7	-352	-345	1	-354	-353	1	-354	-353

When looking at the top four aquifer layers combined it can be seen that for De Pielis the "brook swamp" intervention has the biggest increase in seepage to the fourth aquifer layer. The infiltration however also increases for this intervention. When looking at the SUM for the FLF all interventions show a negative result or no change compared to the BASE model. Also for De Pielis the "brook swamp" intervention is the only intervention with a river inflow, however the river outflow is also increased. If part of this river outflow can be captured within the area it has time to infiltrate into the top aquifer layers.

Table 4.8: Water balance of 2018 for the first aquifer layer for De Pielis. It shows the water balance for the "agricultural abstraction" and "less mowing" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	Agricultural abstraction			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354
OLF	0	0	0	0	0	0
DRN	0	-1	-1	0	-2	-2
RIV	0	0	0	0	-1	-1
FRF	0	0	0	0	0	0
FFF	0	0	0	0	0	0
FLF	1	-354	-353	2	-353	-351

Table 4.9: Water balance of 2018 for the top four aquifer layers combined for De Pielis. It shows the water balance for the BASE model, the "higher water level", "brook swamp" and "closed ditches" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Higher water level			Brook swamp			Closed ditches		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0	0	-1	-1
DRN	0	-7	-7	0	-8	-8	0	-1	-1	0	0	0
RIV	0	-28	-28	0	-25	-25	10	-39	-30	0	-35	-35
FRF	0	-8	-7	0	-7	-7	1	-8	-7	0	-8	-7
FFF	2	-17	-14	2	-16	-14	2	-17	-15	2	-16	-14
FLF	22	-319	-297	21	-321	-300	26	-328	-302	23	-320	-297

Table 4.10: Water balance of 2018 for the top four aquifer layers combined for De Pielis. It shows the water balance for the "agricultural abstraction" and "less mowing" interventions. Where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	Agricultural abstraction			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354
OLF	0	0	0	0	0	0
DRN	0	-4	-4	0	-7	-7
RIV	0	-23	-23	0	-27	-27
FRF	0	-7	-7	0	-8	-7
FFF	2	-16	-14	2	-16	-14
FLF	17	-323	-306	21	-320	-299

4.2.3. Flow paths

In this subsection the flow paths for the single interventions are shown, compared and analysed for the Landschotse Heide and De Pielis. Only the interventions discussed in the previous subsection are shown in this subsection. The flow paths are compared to the flow paths of the BASE model.

Landschotse Heide

Figure 4.9 shows the flow paths for the BASE model and the interventions for the South-North transect. Figure 4.9b shows that more water is able to infiltrate through the clay layers at the South side of the fault with the "higher water level" intervention. This infiltration on the South side can also be seen in Figure 4.10b which shows the flow paths for the West-East transect. It is also visible that there is more seepage North (downstream) of the Landschotse Heide to the top aquifer layers as well as inside the Landschotse Heide area (more blue dots). This is a positive effect for the area itself as well as for downstream areas. Due to this increase in seepage less water is infiltrating through the aquitard at the North side of the fault, resulting in less and different flow paths below this aquitard.

Figure 4.9c shows the flow paths for the "brook swamp" intervention. This figure also shows the extra infiltration through the clay layers at the South side of the fault, as well as more seepage downstream and within the area of the Landschotse Heide to the top aquifer layers. The seepage downstream is however located closer to the Landschotse Heide as for the "higher water level" intervention. Due to this seepage less water is infiltrating through the aquitard layer downstream of the fault. Resulting in different flow paths below this aquitard.

When looking at the West-East transect for this intervention it can be seen that there are more flow paths infiltrating through the aquitard layer than for the "higher water level" intervention (see Figure 4.10c. Because more water is infiltration at the South side of the fault and more water is seeping to higher aquifer layers at the North side of the fault less water is able to flow to the lower aquifer layers more downstream. This might have an effect on the water availability for downstream areas.

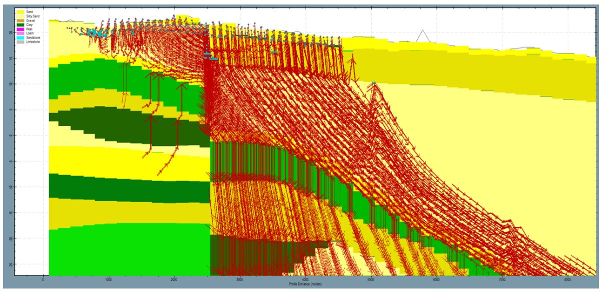
Figure 4.9d shows the flow paths for the "closed ditches" intervention. It shows that only at the downstream side there is a bit more seepage to the top aquifer layers at the same location as for the "brook swamp" intervention. No other big changes are visible, also when looking at the West-East transect (Figure 4.10d).

The small upward flow downstream for the BASE model has disappeared when looking at the "agricultural abstraction" intervention (see Figure B.101c). There is also less seepage visible at the South side of the fault. This can also be seen in Figure B.102c.

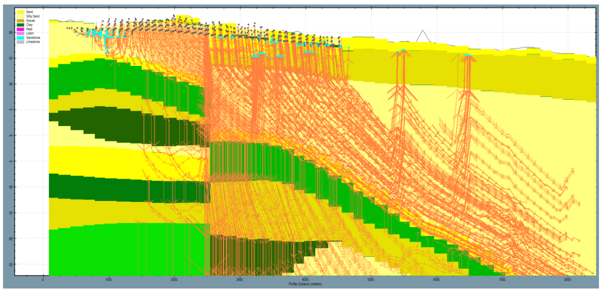
For the "less mowing" intervention there is also a bit more seepage to the higher aquifer layers downstream visible (see Figure 4.9f). There are no other changes visible, also when looking at the West-East transect (Figure 4.10f).

De Pielis

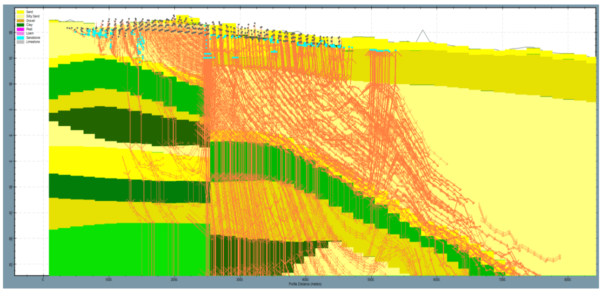
Figures 4.11 and 4.12 show the flow paths for the BASE model and the single interventions for the South-North and West-East transects respectively for the starting point in and surrounding De Pielis area. For the South-North transect it shows that the "higher water level", "brook swamp" and "closed ditches" interventions result in more upward flow to the top aquifer layers downstream of De Pielis. For the "agricultural abstraction" intervention this small flow in the top aquifer layers downstream of De Pielis disappears. It is also visible that the flow paths in the North part of De Pielis change direction toward the abstraction point (to the South). Because of the abstraction point at a depth of around -60 $mNAP$ there are less flow paths going down from that depth to lower aquifer layers. There are no other big changes visible for this transect. For the West-East transect a bit more infiltration at the lower East side is visible for the "higher water level", "brook swamp" and "closed ditches" interventions. There are also some small differences visible at the seepage points for these intervention (blue dots West of De Pielis). The "agricultural abstraction" and "less mowing" interventions do not seem to change the flow paths for this transect.



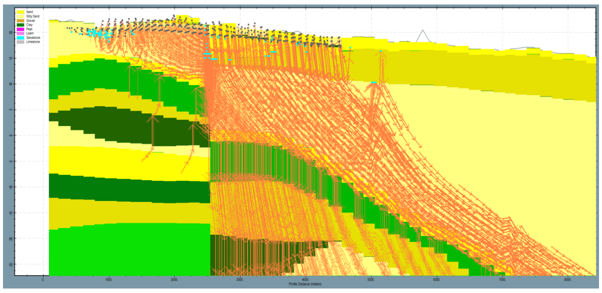
(a) BASE model



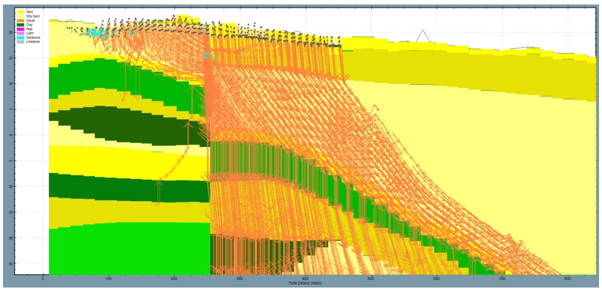
(b) "higher water level" intervention



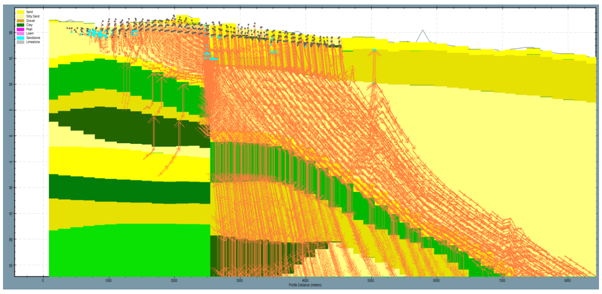
(c) "brook swamp" intervention



(d) "closed ditches" intervention

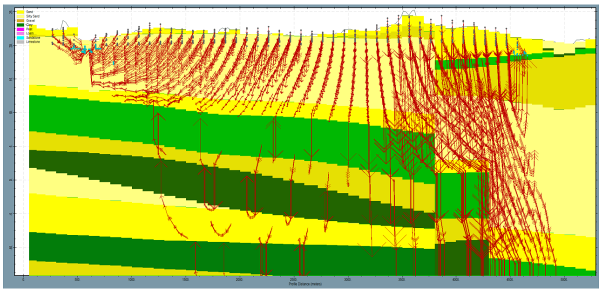


(e) "agricultural abstraction" intervention

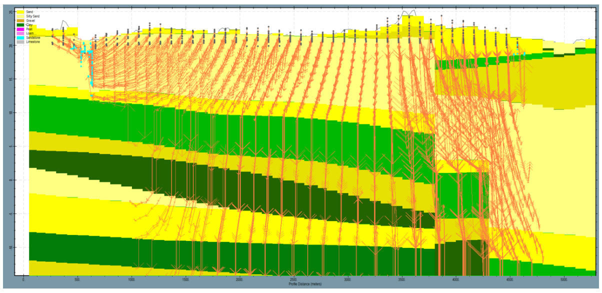


(f) "less mowing" intervention

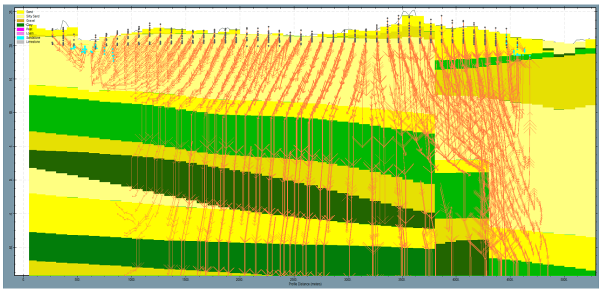
Figure 4.9: Flow paths for the Landschotse Heide and its surroundings for the single interventions, for the South-North transect.



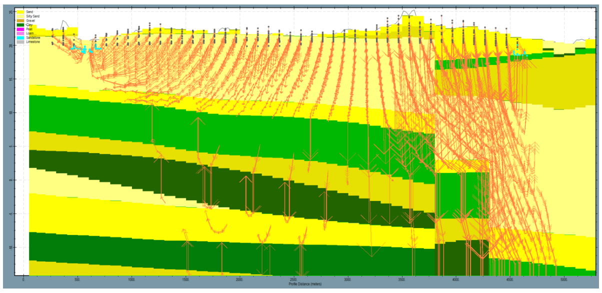
(a) BASE model



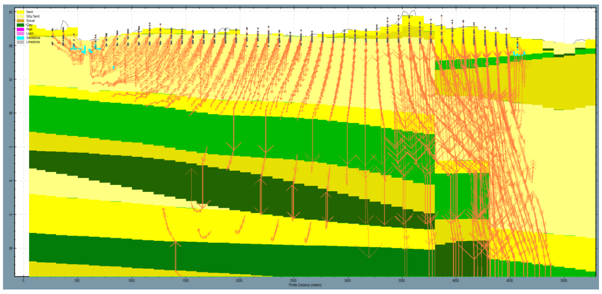
(b) "higher water level" intervention



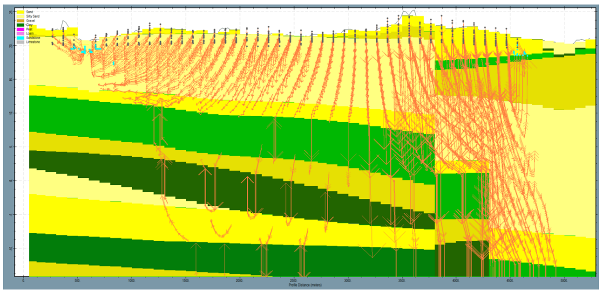
(c) "brook swamp" intervention



(d) "closed ditches" intervention

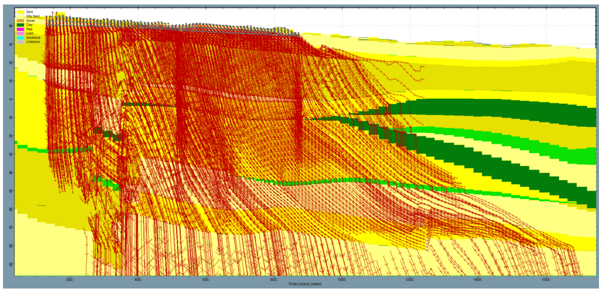


(e) "agricultural abstraction" intervention

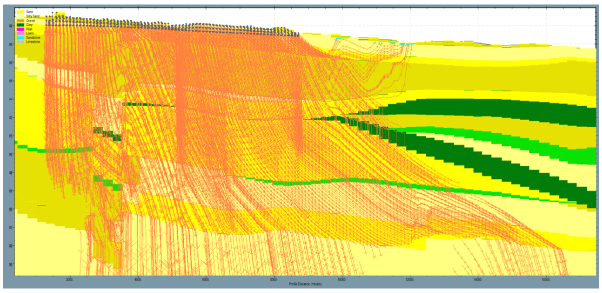


(f) "closed ditches" intervention

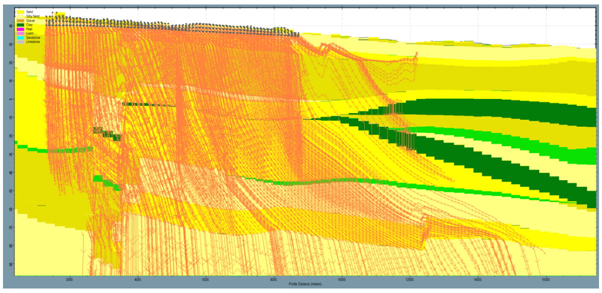
Figure 4.10: Flow paths for the Landschotse Heide and its surroundings for the single interventions, for the West-East transect.



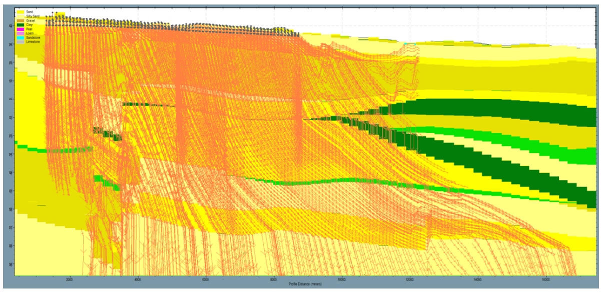
(a) BASE model



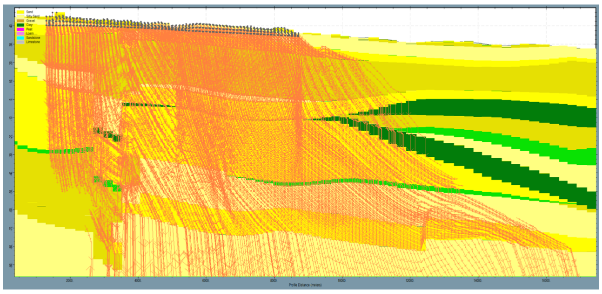
(b) "higher water level" intervention



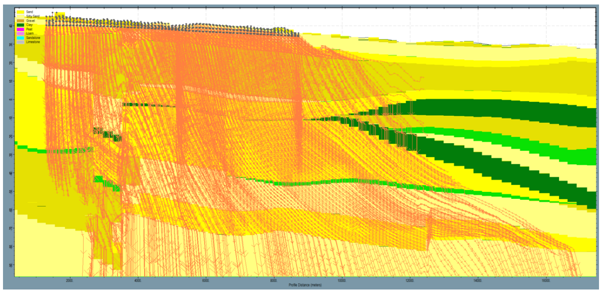
(c) "brook swamp" intervention



(d) "closed ditches" intervention

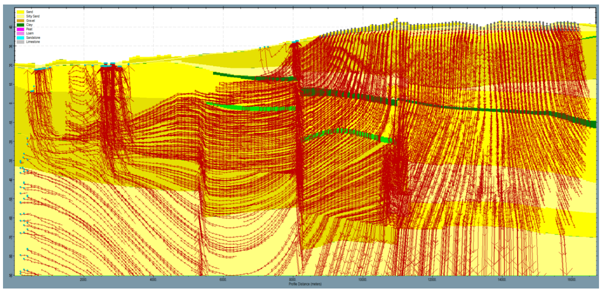


(e) "agricultural abstraction" intervention

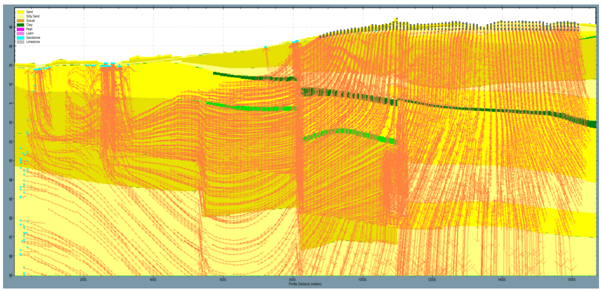


(f) "less mowing" intervention

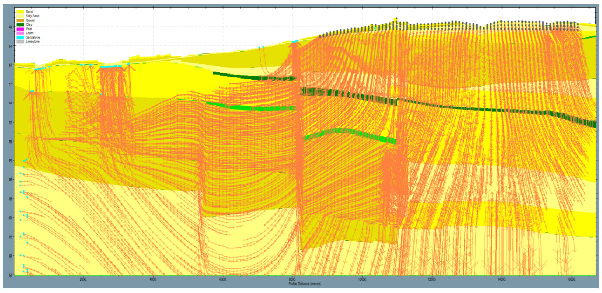
Figure 4.11: Flow paths for De Pielis and its surroundings for the single interventions, for the South-North transect.



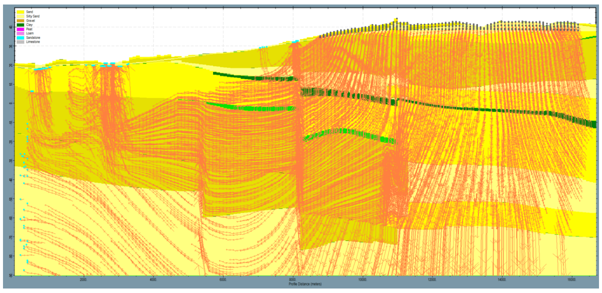
(a) BASE model



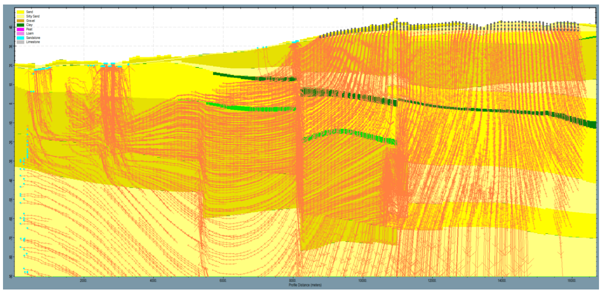
(b) "higher water level" intervention



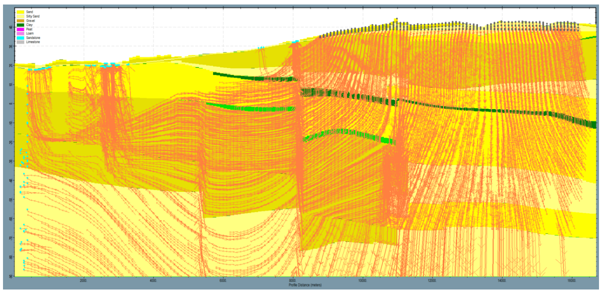
(c) "brook swamp" intervention



(d) "closed ditches" intervention



(e) "agricultural abstraction" intervention



(f) "less mowing" intervention

Figure 4.12: Flow paths for De Pielis and its surroundings for the single interventions, for the West-East transect.

4.3. Combined interventions

This section shows the results of the combined interventions. The combined interventions are based on the single interventions. The "higher water level" intervention and the "closed ditches" intervention show the biggest positive results. In this section the results for combining these interventions is shown as well as combining them only for the area of the Landschotse Heide in a buffer area of 1 km around the area because there the biggest changes in the signals are visible. When looking at interventions within or close to the area of the Landschotse Heide the "climate buffer" intervention can be combined with the "effluent infiltration" intervention. These combined interventions have also been modeled combined with the climate scenarios. The results of these combinations can be found in the Appendix.

4.3.1. Head

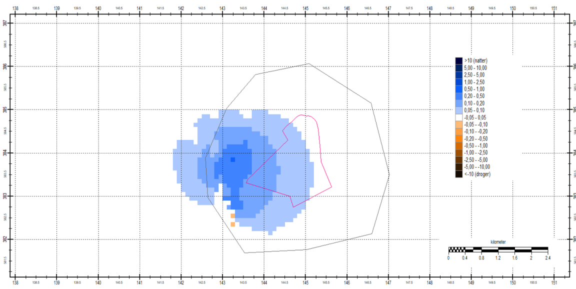
This subsection shows the differences of the heads for the first aquifer layer for the combined interventions compared to the BASE model. These heads are compared and analysed.

Landschotse Heide

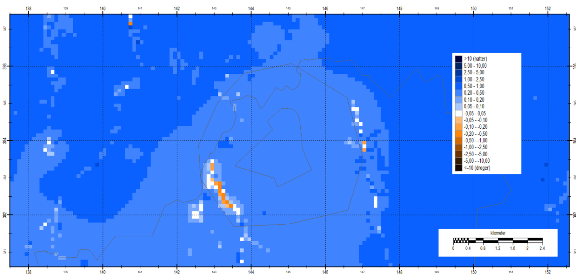
Figure 4.13 shows the head differences for the combined interventions compared to the BASE model for the first aquifer layer. When looking at the "climate buffer" intervention, it can be concluded that, in this situation, with an intervention at a small area, also a small area is affected. What is unexpected is that this effect is more to the West instead of at the Landschotse Heide itself. This shows that interventions are better implemented upstream of the area where the results are desired than at the area itself.

When looking at the combined interventions of the "higher water level" and the "closed ditches", it can be seen that combining these two interventions has a big positive result for the areas around the Landschotse Heide. For the Landschotse Heide itself this combination has a less positive effect, where there are less B- and C-waterways. When comparing this result with the "climate buffer" intervention, it can be concluded that a lot of changes in the upstream part need to be done to have a big positive result for the whole are of the Landschotse Heide.

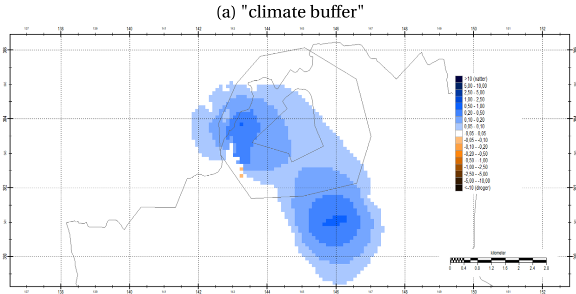
When looking at the combined interventions of the "climate buffer" and the "effluent infiltration", it can be seen that they have there own effect on the area and combine this positive effect in the centre of the Landschotse Heide. They do increase their positive effect a bit and therefore compliment each other.



(a) "climate buffer"



(b) Higher water level and closed ditches



(c) "climate buffer" and "effluent infiltration"

Figure 4.13: Head difference for the Landschotse Heide and its surroundings for the combined interventions compared to the BASE model (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

De Pielis

For De Pielis only the combination of the interventions of the "higher water level" and "closed ditches" is expected to have a result. Figure 4.14 shows the Head difference for the first aquifer layer for this combination compared to the BASE model. It shows that combining these interventions has a big positive effect on the Head for De Pielis and more downstream, but not as much as for the Landschotse Heide.

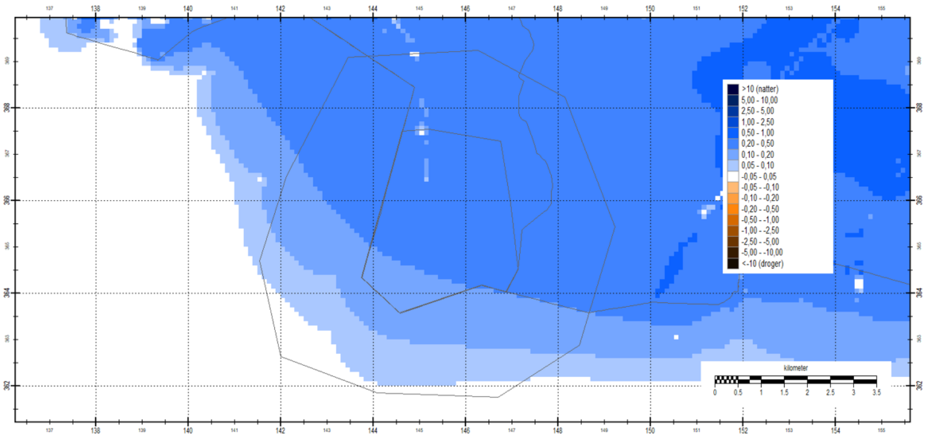


Figure 4.14: Head difference for De Pielis and its surroundings for "higher water level" and "closed ditches" interventions combined intervention compared to the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

4.3.2. Water balance

In this section the water balances for the BASE model and the combined interventions are shown, compared and analysed for the Landschotse Heide and De Pielis.

Landschotse Heide

Table 4.11 shows the water balance for the BASE model and the combined interventions for the first aquifer layer for the Landschotse Heide. It can be seen that the combination of the "higher water level" and "closed ditches" interventions work best. This can be explained by the fact that these interventions are implemented in the whole area of De Dommel. It does have a lot over overland flow, this is only a positive result when this overland flow can be captured within the Landschotse Heide area, in the fens for example.

The other two combined interventions only interfere in and close to the area of the Landschotse Heide. When comparing the "climate buffer" intervention with the "climate buffer" combined with the "effluent infiltration" intervention it can be seen that there is almost no difference in the Water balance for this first aquifer layer. This indicates that the "effluent infiltration" intervention does not contribute that much to the positive change in the water balance of the first aquifer layer.

Table 4.12 shows the water balance for the BASE model and the combined interventions for the top four aquifer layers combined for the Landschotse Heide. Also here the combined intervention of the "higher water level" and "closed ditches" has the biggest positive effect. The "climate buffer" intervention seems to have negative results: the seepage becomes less while the infiltration increases and the net horizontal outflow increases as well. In this case there is a difference visible for the "climate buffer" intervention and the combination of the "climate buffer" and "effluent infiltration" interventions. All posts give a positive result when compared to the BASE model except for the drainage and river outflow. These become less, especially the river outflow decreases.

De Pielis

Table 4.13 shows the water balance for BASE model and the combined interventions for the first aquifer layer for De Pielis. As expected the water balance for the "climate buffer" intervention and the "climate buffer" combined with the "effluent infiltration" show no difference with the BASE model. These interventions are taken close to the Landschotse Heide and do not have an effect on the water balance for the first aquifer in De Pielis. The combined intervention of the "higher water level" and "closed ditches" does show positive results. Especially the increase of seepage is a positive results. This results in overland flow and river outflow. These

Table 4.11: Water balance for the first aquifer layer for the Landschotse Heide for the combined interventions, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Climate buffer			HWL + CD			CB + EfllInf		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	-20	-20	0	0	0
DRN	0	-1	-1	0	-2	-2	0	0	0	0	-2	-2
RIV	0	-25	-25	0	-28	-28	0	-39	-39	0	-28	-28
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	15	-284	-269	19	-283	-265	42	-278	-236	19	-283	-264

Table 4.12: Water balance for the top four aquifer layers combined for the Landschotse Heide for the combined interventions, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Climate buffer			HWL + CD			CB + EfllInf		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	-20	-20	0	0	0
DRN	0	-8	-8	0	-7	-7	0	0	0	0	-7	-7
RIV	0	-104	-104	0	-91	-91	0	-134	-134	0	-92	-92
FRF	15	-28	-12	13	-29	-16	30	-33	-3	17	-39	-22
FFF	30	-89	-59	29	-91	-62	42	-102	-60	43	-114	-71
FLF	29	-140	-111	24	-144	-120	38	-116	-78	28	-130	-103

are only positive results when this can be captured inside the area.

Table 4.14 shows the water balance for the BASE model and combined interventions for the top four aquifer layers combined for De Pielis. Also here there is no difference visible for the "climate buffer" intervention compared to the BASE model. However there is a difference visible for the combination of the "climate buffer" and "effluent infiltration" interventions. This shows that changes in deeper aquifer layers in and around the Landschotse Heide have a change on the water balance in De Pielis. The seepage to the fourth layer halves but the infiltration to the fifth layer also decreases, even more than the seepage resulting in a positive change for the net FLF. Both the "higher water level" and "closed ditches" intervention and the "climate buffer" and "effluent infiltration" intervention result in more horizontal net outflow. For De Pielis this is not a positive result, but for downstream areas it is.

Table 4.13: Water balance for the first aquifer layer for De Pielis for the combined interventions, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			Climate buffer			HWL + CD			CB + EfllInf		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	-8	-8	0	0	0
DRN	0	-1	-1	0	-1	-1	0	0	0	0	-1	-1
RIV	0	0	0	0	0	0	0	-2	-2	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	1	-353	-352	1	-353	-352	8	-352	-344	1	-353	-352

Table 4.14: Water balance for the top four aquifer layers combined for De Pielis for the combined interventions, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

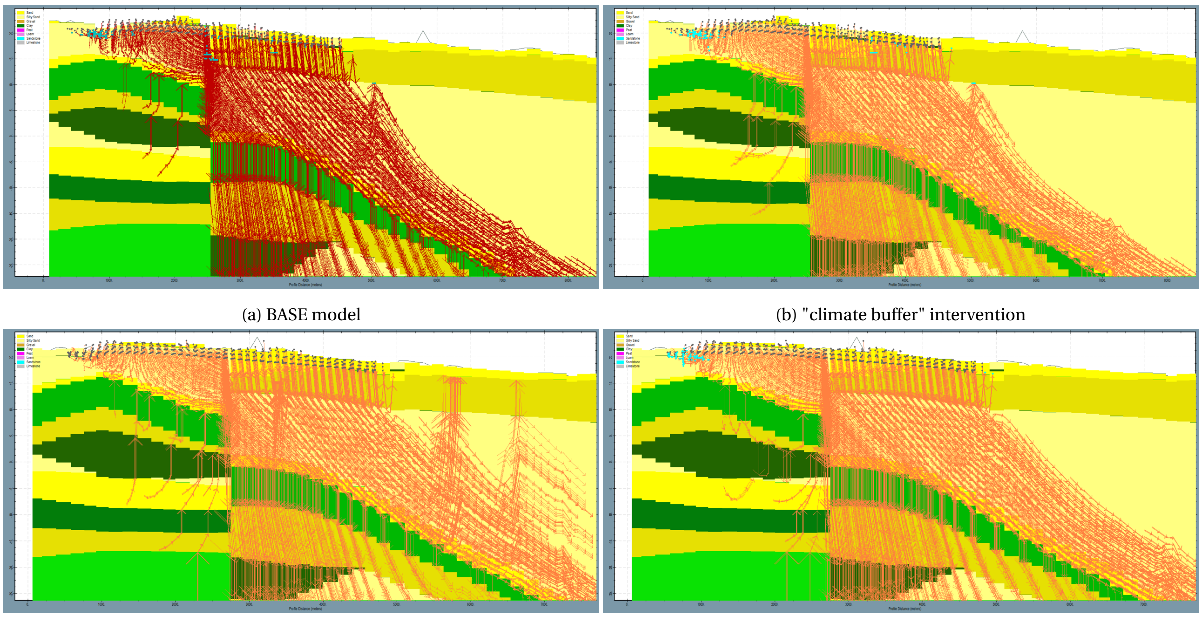
	BASE model			Climate buffer			HWL + CD			CB + Efll. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	-8	-8	0	0	0
DRN	0	-7	-7	0	-7	-7	0	0	0	0	-7	-7
RIV	0	-28	-28	0	-28	-28	0	-30	-30	0	-32	-32
FRF	0	-8	-7	0	-8	-7	1	-32	-31	2	-33	-31
FFF	2	-17	-14	2	-17	-14	8	-44	-36	9	-45	-36
FLF	22	-319	-297	22	-319	-297	9	-260	-250	10	-257	-247

4.3.3. Flow paths

In this subsection the flow paths for the combined interventions are shown, compared and analysed for the Landschotse Heide and De Pielis. The flow paths are also compared to the flow paths of the BASE model.

Landschotse Heide

Figures 4.15 and 4.16 show the flow paths for the BASE model and the combined interventions for the South-North and West-East transects for the Landschotse Heide. For the South-North transect the biggest changes are visible for the "higher water level" and "closed ditches" combination. This intervention results in a lot of seepage to the top aquifer layers downstream of the Landschotse Heide and also more seepage within the area of the Landschotse Heide. There is also more seepage at the South side of the fault visible, this is also visible in the West-East transect. Because of this increase in seepage less groundwater is infiltrating through the aquitard at the North side of the fault resulting in less flow paths below this aquitard. Also the combined intervention of the "climate buffer" and "effluent infiltration" shows some differences compared to the BASE model. There is more seepage at the South side of the fault and there are more flow lines in the lower right corner visible. For the West-East transect this increase in seepage is however not visible. The "climate buffer" intervention does not show much differences for this transect. For the West-East transect this intervention shows less infiltration through the lowest aquitard, and more seepage through this aquitard.



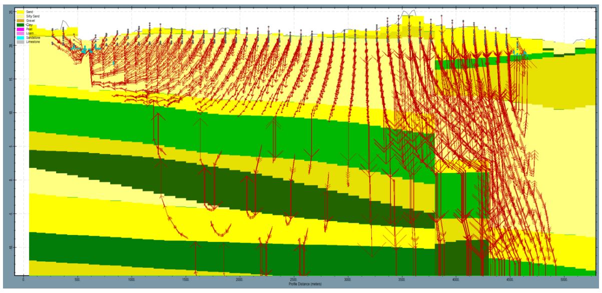
(a) BASE model

(b) "climate buffer" intervention

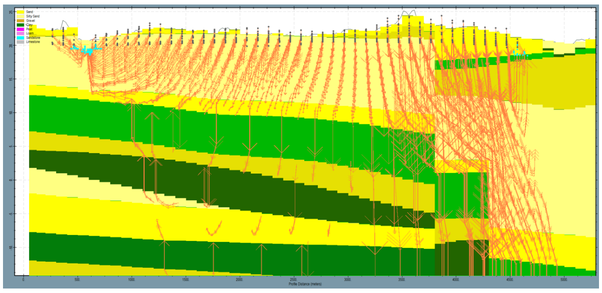
(c) "higher water level" combined with the "closed ditches" interventions

(d) "climate buffer" combined with the "effluent infiltration" interventions

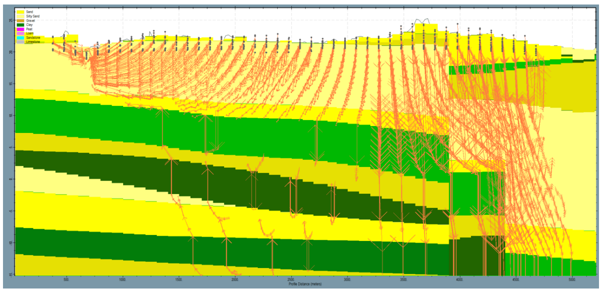
Figure 4.15: Flow paths for the Landschotse Heide and its surroundings for the combined interventions, for the South-North transect.



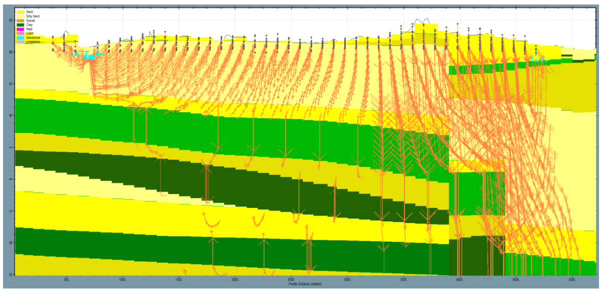
(a) BASE model



(b) "climate buffer" intervention



(c) "higher water level" combined with the "closed ditches" interventions

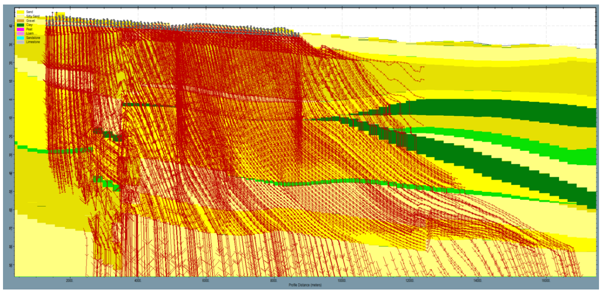


(d) "climate buffer" combined with the "effluent infiltration" interventions

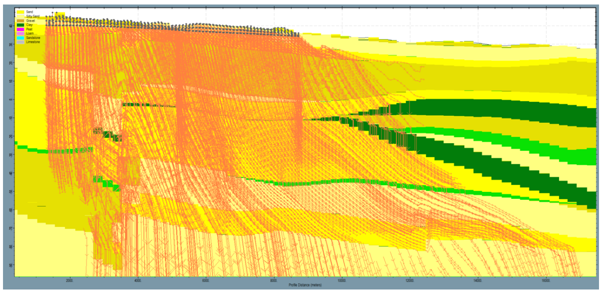
Figure 4.16: Flow paths for the Landschotse Heide and its surroundings for the combined interventions, for the West-East transect.

De Pielis

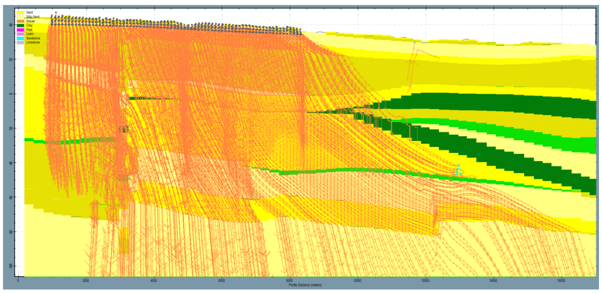
Figures 4.17 and 4.18 show the flow pahts for the BASE model and combined interventions for the South-North and West-East transects for De Pielis. For the South-North transect the combined intervention of the "higher water level" and "closed ditches" and the combined intervention of the "climate buffer" and "effluent infiltration" show changes in the flow paths at the top in the middle of the figure. No other differences are visible, also for the West-East transect.



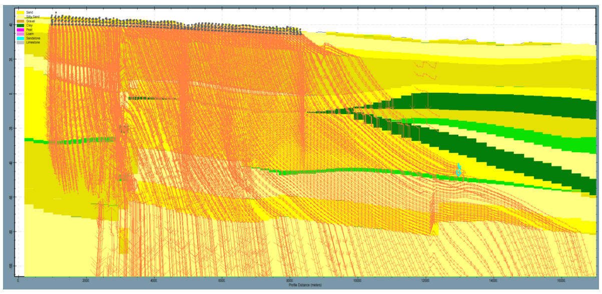
(a) BASE model



(b) "climate buffer" intervention

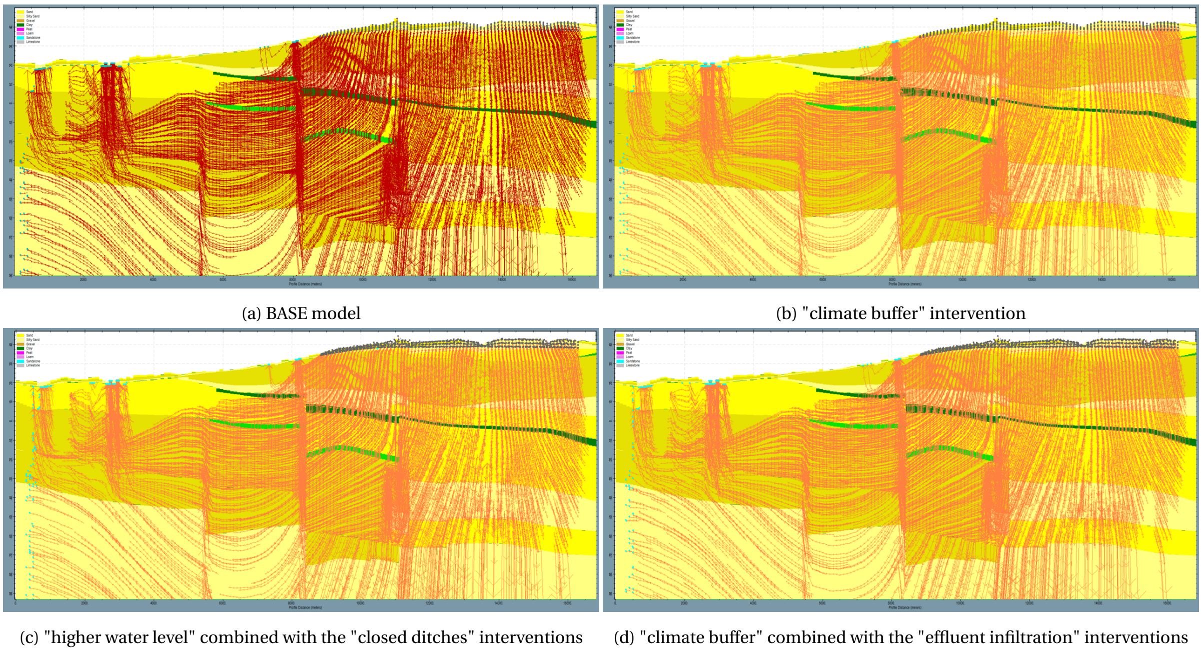


(c) "higher water level" combined with the "closed ditches" interventions



(d) "climate buffer" combined with the "effluent infiltration" interventions

Figure 4.17: Flow paths for De Pielis and its surroundings for the combined interventions, for the South-North transect.



(a) BASE model

(b) "climate buffer" intervention

(c) "higher water level" combined with the "closed ditches" interventions

(d) "climate buffer" combined with the "effluent infiltration" interventions

Figure 4.18: Flow paths for De Pielis and its surroundings for the combined interventions, for the West-East transect.

4.4. Scenarios

In this section the results of the four future climate scenarios and the three abstraction scenarios are shown, compared to the BASE model and analysed. As mentioned in Chapter 2, the abstraction scenarios are included in this research to analyse the effect of water abstraction and to compare these scenarios with the impact of the interventions. The climate scenarios are used to see the effect of the interventions combined with these different climate scenarios.

4.4.1. Head

In this subsection the head differences in the first aquifer layer for the climate and water abstraction scenarios are shown. They area compared to the head of the BASE model and the differences are analysed. Also here, the legend shows the head difference in meters per year.

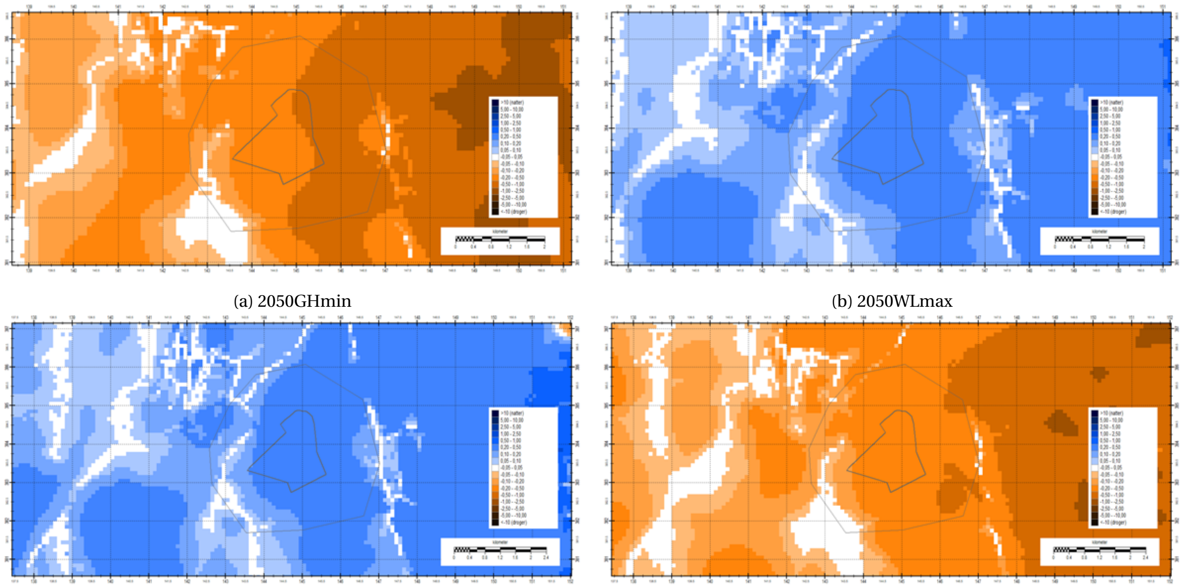
Landschotse Heide

Figure 4.19 shows the Head of the first aquifer layer for the four climate scenarios for the Landschotse Heide. Figures 4.19a and 4.19d show the dryer scenarios, where the scenario for 2050 is dryer than the scenario for 2085. Figures 4.19b and 4.19c show the wetter scenarios, where the scenario for 2085 is wetter. The wet scenarios have the same pattern which might indicate that at other wet scenarios the same pattern of wetness can be expected. The dry scenarios show differences is dryness at the East side of the Landschotse Heide. At the West side they show the same pattern.

Figure 4.20 shows the Head for the first aquifer layer for the three abstraction scenarios for the Landschotse Heide. There is one abstraction point close by as can be seen in these figures. These abstractions happen at depth of 0 till -50 $mNAP$ and still have a big effect on the Head in the top aquifer layer. Especially at the location of the well itself, but it also has a wide range where it affects the Head, including a big part of the Landschotse Heide.

De Pielis

Figure 4.21 shows the Head for the first aquifer layer for the four climate scenarios for De Pielis. Figures 4.21a and 4.21d show the dryer scenarios, where the scenario for 2050 is dryer than the 2085 scenario. Figures 4.21b and 4.21c show the wetter scenarios, where the 2085 scenario is wetter. De Pielis area is in all four scenarios the driest area, in the wetter scenarios De Pielis has the smallest increase in wetness whereas in the dryer scenarios De Pielis has the biggest increase in dryness. Also for this area patterns are visible for the wetter



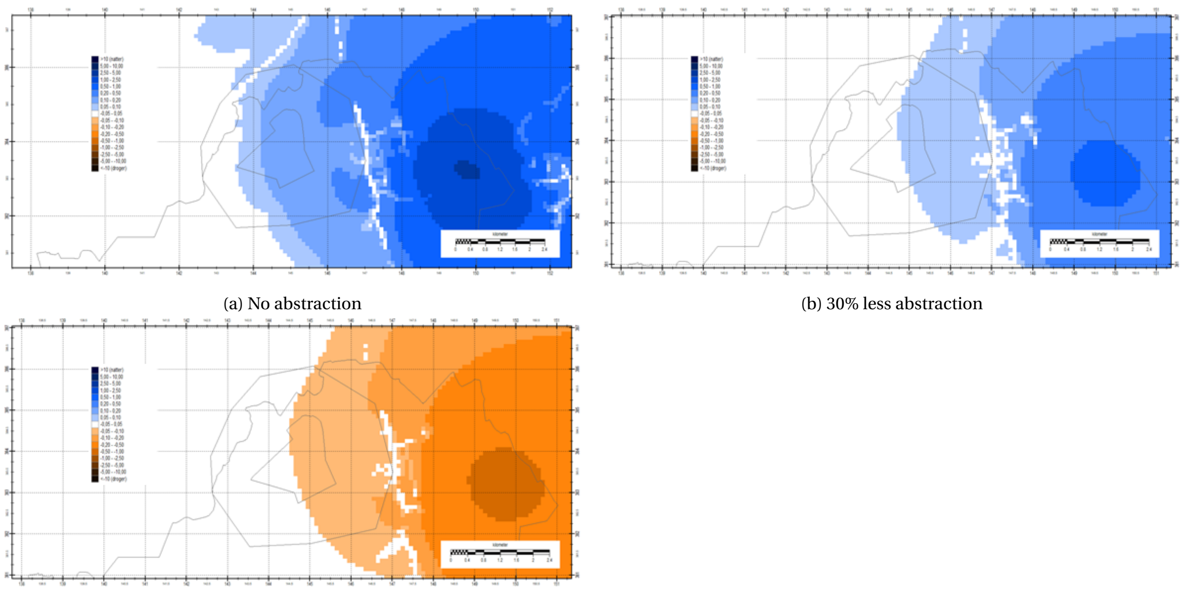
(a) 2050GHmin

(b) 2050WLmax

(c) 2085GLmax

(d) 2085WHmin

Figure 4.19: Head difference for the Landschotse Heide and its surroundings for the Climate scenarios compared to the BASE model (legend in $meters$, 'natter'=wetter, 'droger'=dryer).



(a) No abstraction

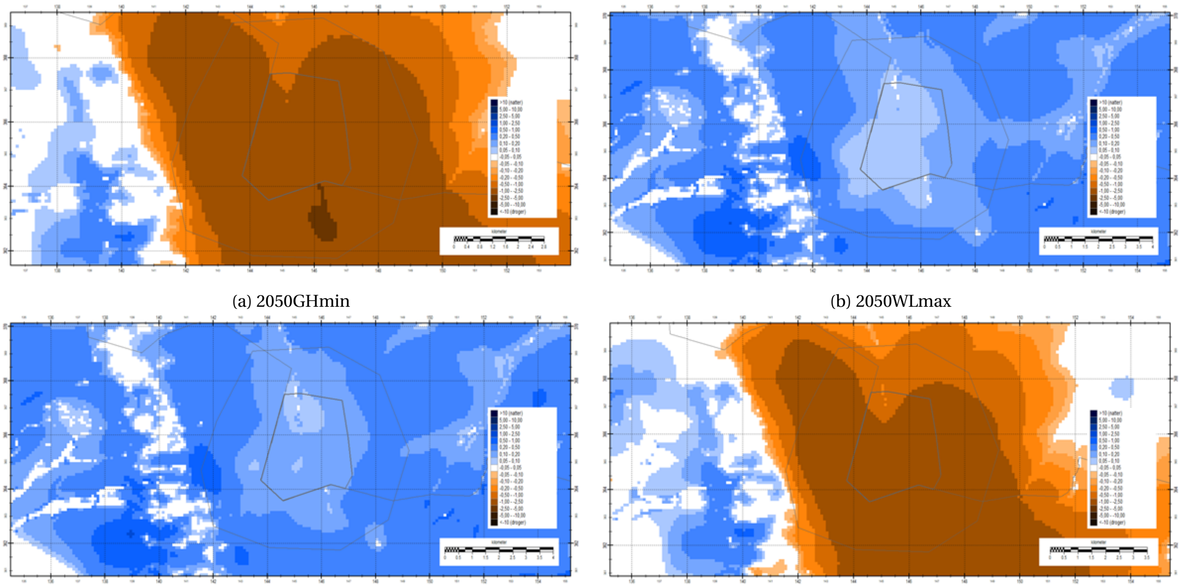
(b) 30% less abstraction

(c) 30% more abstraction

Figure 4.20: Head difference for the Landschotse Heide and its surroundings for the abstraction scenarios compared to the BASE model (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

scenarios and the dryer scenarios.

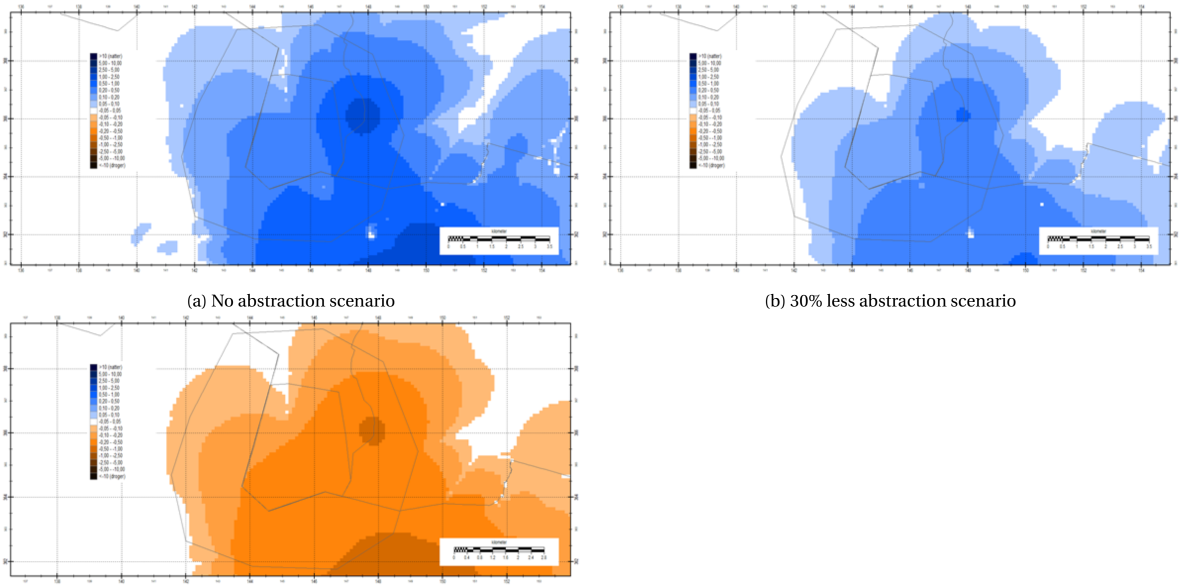
Figure 4.22 shows the Head for the first aquifer layer for the three abstractions scenarios for De Pielis. Also close to De Pielis there is an abstraction well as can be seen in the figure. This well is also abstracting deep into the subsoil (below -300 $mNAP$), but a big area in the top aquifer layer is effected by this well as can be seen in this figure.



(a) 2050GHmin (b) 2050WLmax

(c) 2085GLmax (d) 2085WHmin

Figure 4.21: Head difference for De Pielis and its surroundings for the four Climate scenarios compared to the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).



(a) No abstraction scenario (b) 30% less abstraction scenario

(c) 30% more abstraction scenario

Figure 4.22: Head difference for De Pielis and its surroundings for the abstraction scenarios compared to the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

4.4.2. Water balance

In this subsection the water balance of the climate and abstraction scenarios are shown, compared and analysed for the Landschotse Heide and De Pielis.

Landschotse Heide

Tables 4.15 and 4.16 show the water balances for the four climate scenarios for the Landschotse Heide for the first aquifer layer and the top four aquifer layers combined respectively. Tables 4.17 and 4.18 show the water balances for the BASE model and the three abstraction scenarios for the Landschotse Heide for the first aquifer layer and the top four aquifer layers combined respectively.

It can be seen that the dryer climate scenarios have way less drainage and river outflow than the wetter scenarios. In terms of percentage there is more water infiltrating to lower layers in the dryer scenarios when looking at the amount of Recharge and the amount of infiltration. When looking at the top four aquifer layers combined and comparing them to the BASE model the SUM values for the FRF, FFF and FLF do not differ that much. The drainage and river outflow show bigger differences compared to the BASE model.

The water balance for the abstraction scenarios show for the fist aquifer layer small changes for the river outflow. The No abstraction scenario also changes the drainage outflow. As expected, the No abstraction scenario shows the biggest and most positive changes, mostly for the seepage and infiltration (FLF). For the top four aquifer layers there is more difference visible for the 30% less and 30% more abstraction scenarios. Especially for the river outflow and infiltration to the fifth aquifer layer. The horizontal flow does not change much for all three scenarios, which can be expected as the abstraction well are located at deeper aquifer layers resulting in changes in vertical flow. The differences for the No abstraction and 30% less abstraction scenarios are about the same as the differences for the 30% less and 30% more abstraction scenarios. Only for the drainage outflow the difference is bigger.

Table 4.15: Water balance for the first aquifer layer for the Landschotse Heide for the four Climate scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	2050GHmin			2050WLmax			2085GLmax			2085WHmin		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	363	0	363	367	0	367	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-5	-5	0	-5	-5	0	-1	-1
RIV	0	-18	-18	0	-35	-35	0	-35	-35	0	-19	-19
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	11	-232	-220	20	-344	-323	21	-347	-326	12	-242	-229

Table 4.16: Water balance for the top four aquifer layers combined for the Landschotse Heide for the four Climate scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	2050GHmin			2050WLmax			2085GLmax			2085WHmin		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	363	0	363	367	0	367	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-3	-3	0	-17	-17	0	-18	-18	0	-4	-4
RIV	0	-60	-60	0	-153	-153	0	-157	-157	0	-68	-68
FRF	10	-25	-15	18	-32	-14	18	-32	-14	11	-26	-15
FFF	31	-85	-55	30	-92	-62	30	-92	-62	30	-86	-55
FLF	19	-125	-106	36	-152	-116	37	-153	-116	20	-128	-108

De Pielis
Tables 4.19 and 4.20 show the water balances for the first aquifer layer and the top four aquifer layers combined for the four climate scenarios for De Pielis. Tables 4.21 and 4.22 show the water balances for the first aquifer layer and the top four aquifer layers combined for the BASE model and the three abstraction scenarios for De Pielis.

It can be seen that for the dryer climate scenarios there is no drainage and almost no river flow left. The horizontal flow has also decreased and the seepage to the first and fourth aquifer layer has gone to almost nothing. In these scenarios almost all the recharge water will flow to the deeper layers. The wetter scenarios result in more drainage and river outflow. The horizontal flow does not change much compared to the BASE

Table 4.17: Water balance for the first aquifer layer for the Landschotse Heide for the three abstraction scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-4	-4	0	-1	-1	0	-1	-1
RIV	0	-25	-25	0	-28	-28	0	-26	-26	0	-24	-24
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	15	-284	-269	18	-281	-263	16	-283	-268	15	-284	-270

Table 4.18: Water balance for the top four aquifer layers combined for the Landschotse Heide for the three abstraction scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-8	-8	0	-14	-14	0	-9	-9	0	-8	-8
RIV	0	-104	-104	0	-121	-121	0	-110	-110	0	-99	-99
FRF	15	-28	-12	17	-23	-7	16	-26	-10	15	-30	-15
FFF	30	-89	-59	29	-90	-62	29	-89	-60	30	-88	-58
FLF	29	-140	-111	34	-126	-92	30	-135	-105	27	-144	-117

model. The infiltration to the fifth aquifer layer does not change much but the seepage to the fourth aquifer layer does increase for the wetter climate scenarios compared to the BASE model.

Table 4.19: Water balance for the first aquifer layer for De Pielis for the four Climate scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	2050GHmin			2050WLmax			2085GLmax			2085WHmin		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	363	0	363	367	0	367	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-5	-5	0	-6	-6	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-239	-239	3	-360	-357	3	-363	-360	0	-249	-249

For the first aquifer layer there is a change in the drainage outflow and seepage to the first aquifer layer for the No abstraction scenario. This change is also visible for the 30% less abstraction, only smaller. The no abstraction scenario shows a big positive effect for the top four aquifer layers combined. There is way more drainage and river outflow and seepage to the fourth aquifer layer. For this are the difference between the No abstraction scenario and the 30% less abstraction scenario are bigger than the differences between the 30% less and 30% more abstraction scenarios. This might be explained by the thick sand layer in this area which has a high permeability.

Table 4.20: Water balance for the top four aquifer layers combined for De Pielis for the four Climate scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	2050GHmin			2050WLmax			2085GLmax			2085WHmin		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	363	0	363	367	0	367	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-14	-14	0	-15	-15	0	-2	-2
RIV	0	-1	-1	0	-39	-39	0	-41	-41	0	0	0
FRF	0	-4	-4	1	-7	-7	1	-7	-7	0	-5	-5
FFF	2	-12	-10	3	-16	-13	3	-16	-13	2	-12	-10
FLF	1	-226	-225	29	-319	-289	31	-321	-291	1	-234	-233

Table 4.21: Water balance for the first aquifer layer for De Pielis for the three abstraction scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

	BASE model			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-6	-6	0	-2	-2	0	-1	-1
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	1	-353	-352	5	-353	-348	2	-353	-352	1	-354	-353

Table 4.22: Water balance for the top four aquifer layers combined for De Pielis for the three abstraction scenarios, where RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

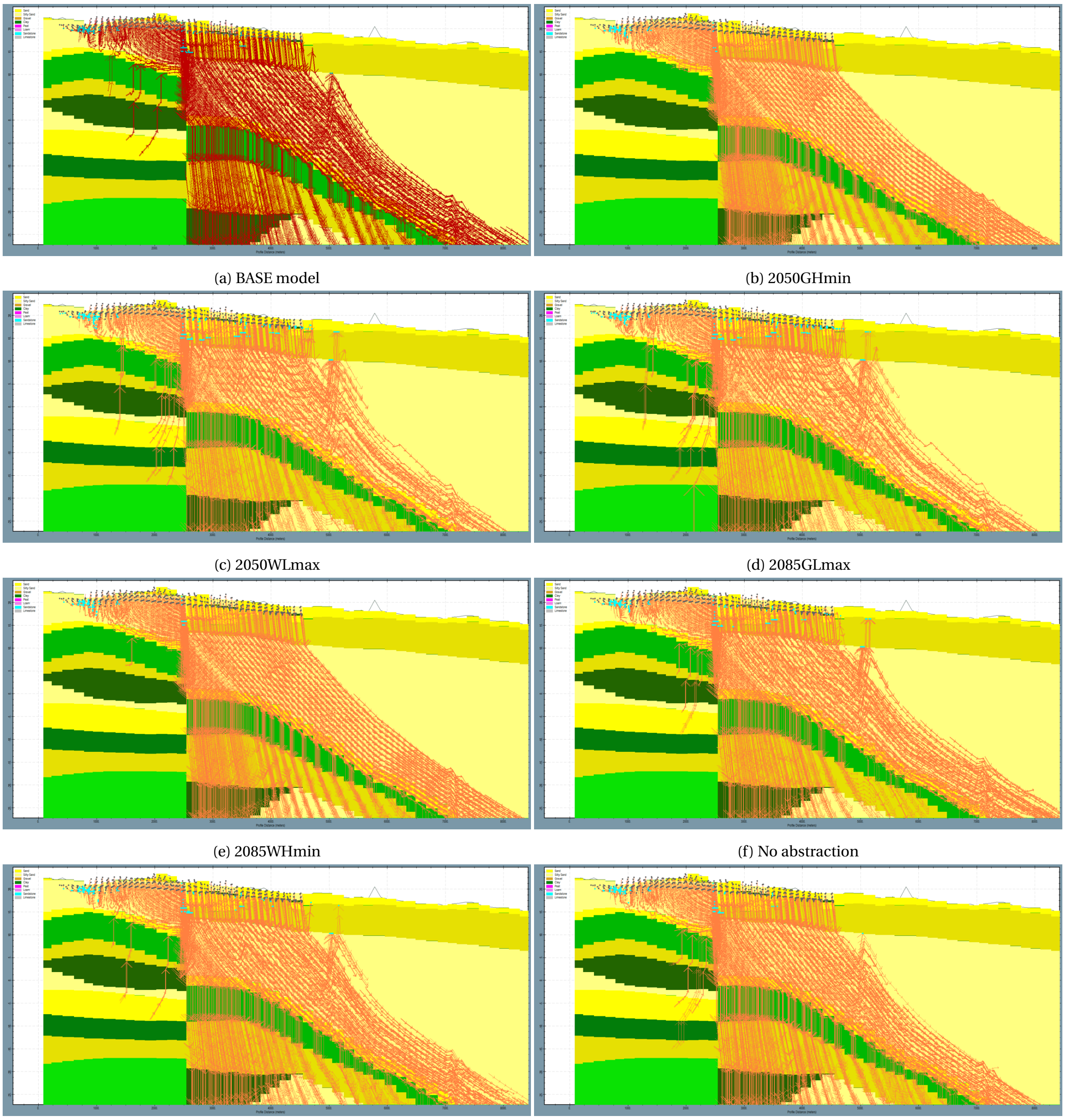
	BASE model			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-7	-7	0	-20	-20	0	-10	-10	0	-5	-5
RIV	0	-28	-28	0	-50	-50	0	-35	-35	0	-23	-23
FRF	0	-8	-7	1	-10	-9	0	-8	-8	0	-7	-6
FFF	2	-17	-14	3	-18	-15	2	-17	-14	2	-16	-14
FLF	22	-319	-297	42	-302	-260	26	-314	-287	17	-323	-306

4.4.3. Flow paths

In this subsection the flow paths for the climate and abstraction scenarios are shown, compared and analysed for the Landschotse Heide and De Pielis. They are compared to the flow paths of the BASE model.

Landschotse Heide

Figures 4.23 and 4.24 show the flow paths for the BASE model and the different climate and abstraction scenarios for the South-North and West-East transects for the Landschotse Heide. For the dryer climate scenarios the seepage at the South side of the fault has disappeared while for the wetter climate scenarios this increases and comes from deeper aquifer layers. The wetter scenarios also show an increase in seepage to the top layers at the North side of the fault within as well as outside the area of the Landschotse Heide. The flow paths of the abstraction scenarios show a big difference. This seepage North of the fault is also visible for the No abstraction and 30% less abstraction scenarios. The scenario with 30% more abstraction shows, South of the fault and in the West-East transect, that the flow paths go to deeper layers, whereas the flow paths for the no abstraction scenario end more at the higher layers, keeping more water at the topsoil.



(a) BASE model

(b) 2050GHmin

(c) 2050WLmax

(d) 2085GLmax

(e) 2085WHmin

(f) No abstraction

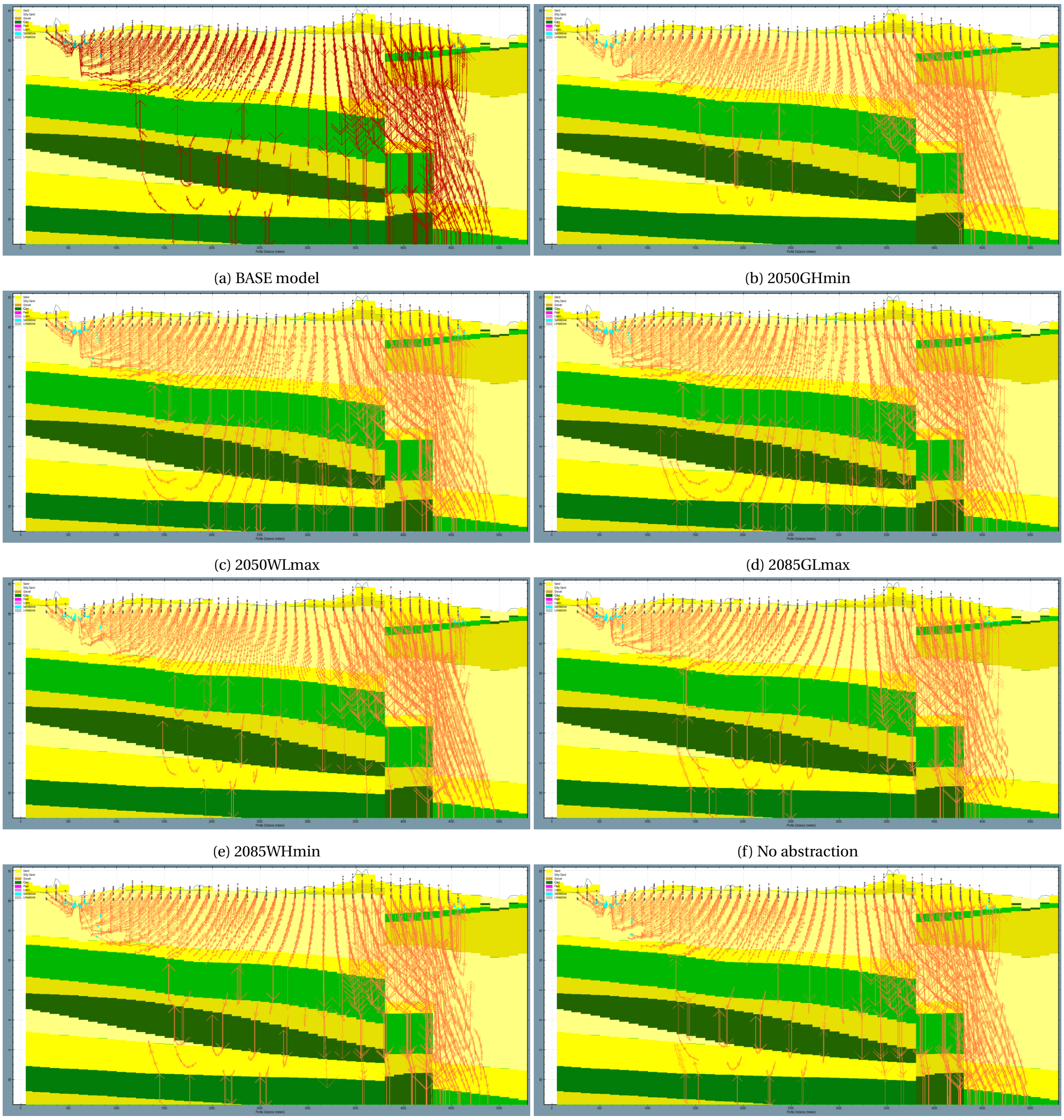
(g) 30% less abstraction

(h) 30% morea abstraction

Figure 4.23: Flow paths for the Landschotse Heide and its surroundings for the climate scenarios, for the South-North transect.

De Pielis

Figures 4.11a and 4.12a show the flow paths for the climate and abstraction scenarios for De Pielis for the South-North and West-East transects respectively. For the dry climate scenarios the flow paths in the top layers downstream disappear for the South-North transect, while for the wet climate scenarios more flow paths are visible at this location. For the West-East transect there are differences visible at the seepage locations in the West. Besides that, for the dry scenarios the infiltration to the lower aquifer layers is less than for the BASE model. For the no abstraction scenario less flow paths are visible in the lower aquifer layers for the South-North transect because there is no more extra suction from deeper aquifer layers. There are more flow paths in the top aquifer layers downstream for these two abstraction scenarios, while for the 30% more abstraction scenario there are less flow paths visible at that location. This scenario also shows in the West-East transect more flow paths to lower aquifer layers at the location of De Pielis. For the no abstraction scenario more seepage to the Goorloop is visible in the West-East transect.



(a) BASE model

(b) 2050GHmin

(c) 2050WLmax

(d) 2085GLmax

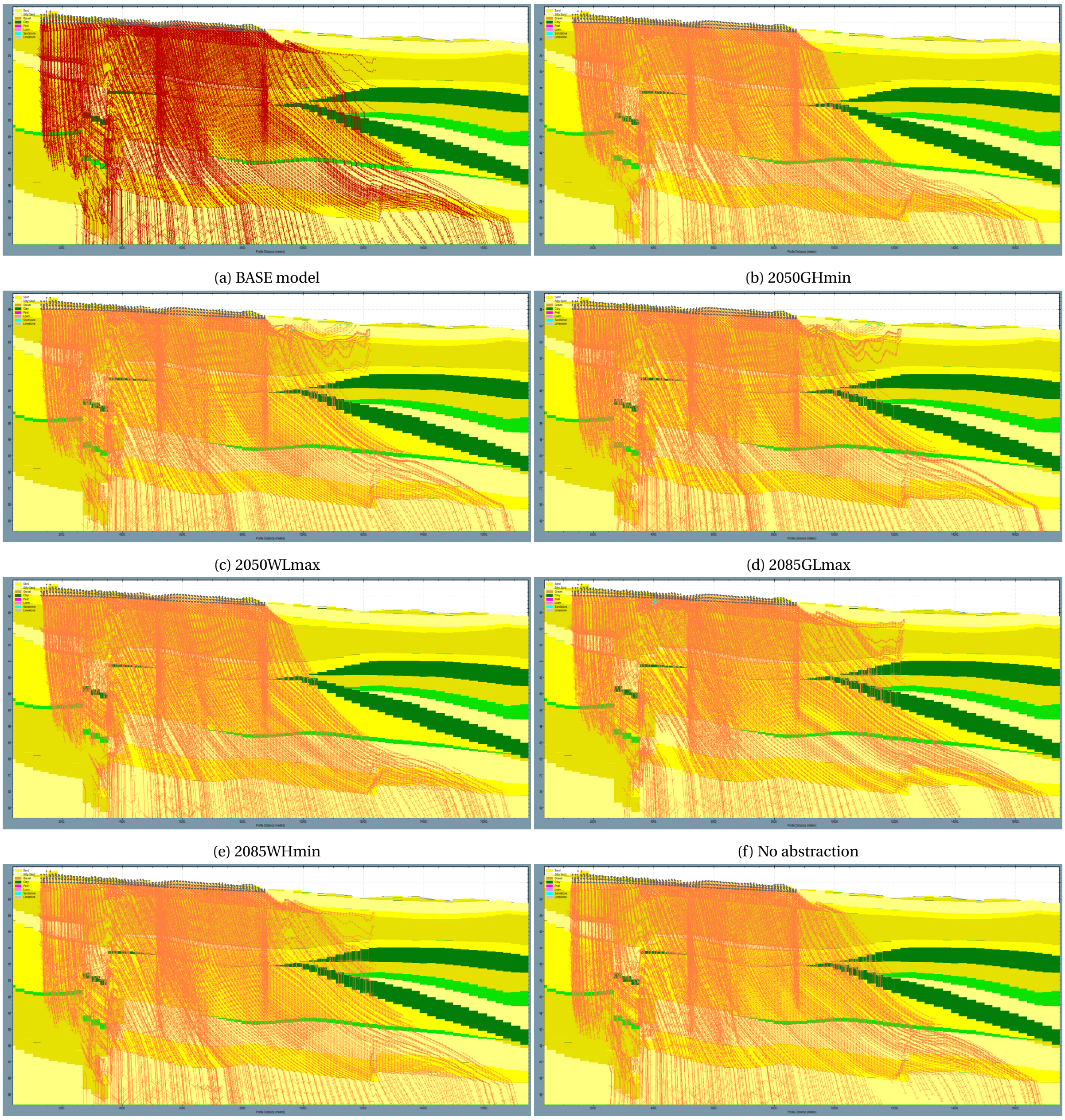
(e) 2085WHmin

(f) No abstraction

(g) 30% less abstraction

(h) 30% more abstraction

Figure 4.24: Flow paths for the Landschotse Heide and its surroundings for the climate and abstraction scenarios, for the West-East transect.



(a) BASE model

(b) 2050GHmin

(c) 2050WLmax

(d) 2085GLmax

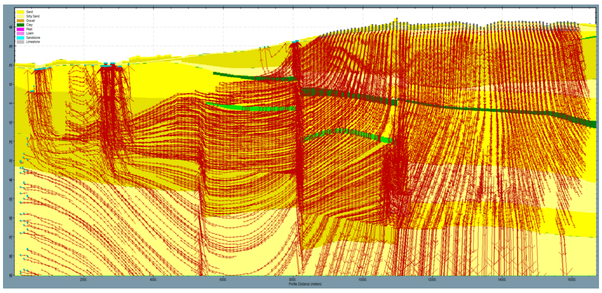
(e) 2085WHmin

(f) No abstraction

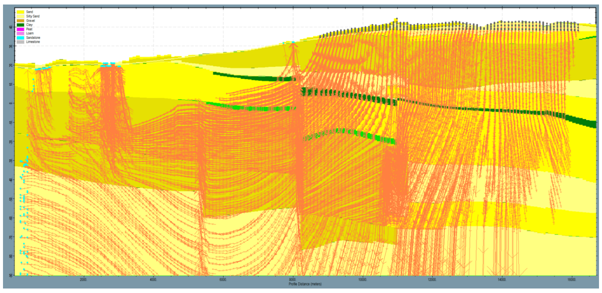
(g) 30% less abstraction

(h) 30% more abstraction

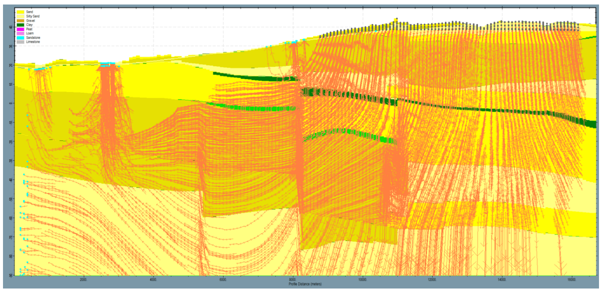
Figure 4.25: Flow paths for De Pielis and its surroundings for the climate and abstraction scenarios, for the South-North transect.



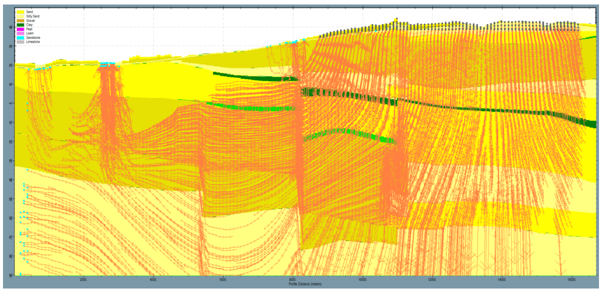
(a) BASE model



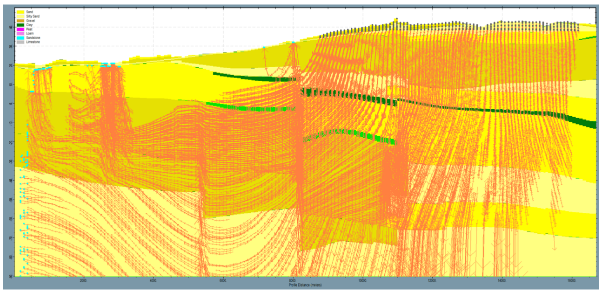
(b) 2050GHmin



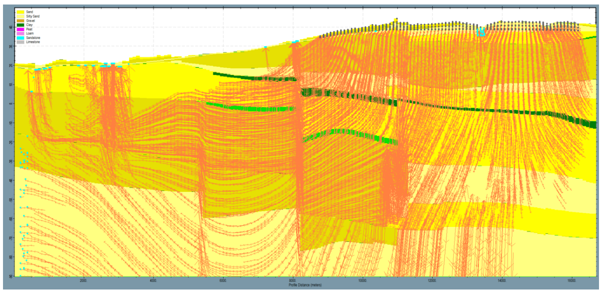
(c) 2050WLmax



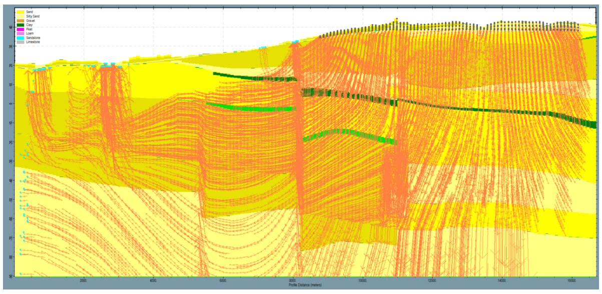
(d) 2085GLmax



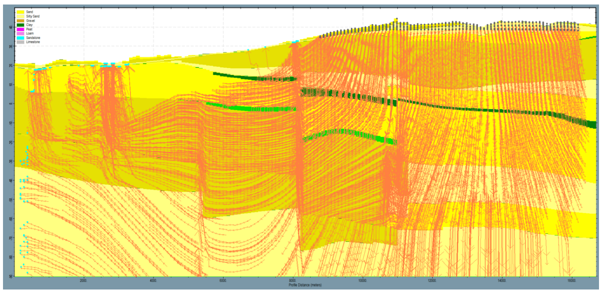
(e) 2085WHmin



(f) No abstraction



(g) 30% less abstraction



(h) 30% more abstraction

Figure 4.26: Flow paths for De Pielis and its surroundings for the climate and abstraction scenarios, for the West-East transect.

4.5. Non-stationary model

In this section the differences between the results of the non-stationary model for the "brook swamp" intervention and the BASE model are discussed. These results are the head-maps and the time series of these heads at three calculation points per area.

4.5.1. Head

Figure 4.27 shows the head differences for the "brook swamp" intervention compared to the non-stationary BASE model for the average high head (AHH), the average low head (ALH) and the average spring head (ASH). Here the different average heads for the "brook swamp" intervention are compared to the different average heads for the BASE model, both with an infiltration factor of 0.3. It shows that for almost the whole catchment it becomes wetter for the "brook swamp" intervention. Also De Pielis and the Landschotse Heide areas become wetter for all three average heads. This corresponds to the expectations for this intervention. Compared to the stationary model the non-stationary model has a more positive outcome.

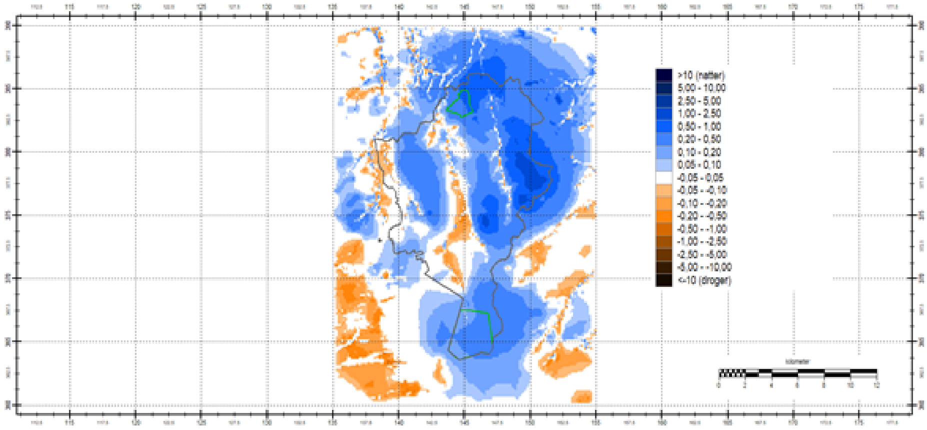
4.5.2. Time-series

The time series discussed in this section are the time series of the heads of the top aquifer layer for the year 2018. The location of these time series is shown in Figures 2.4 and 2.5.

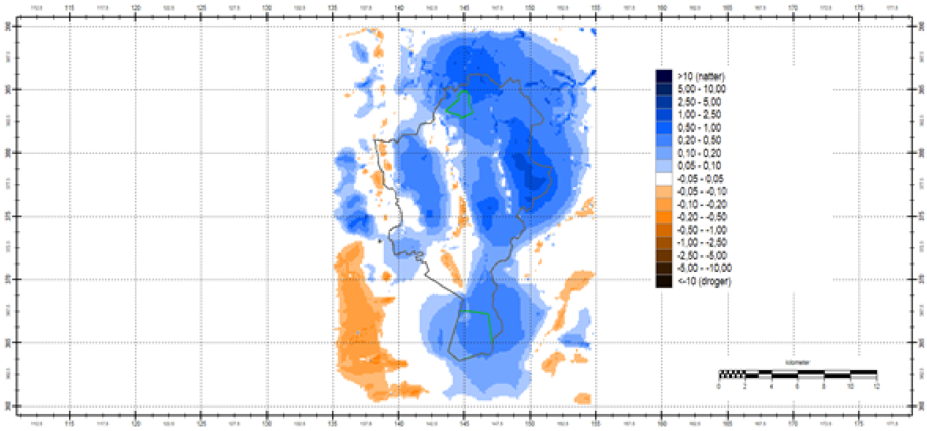
Figure 4.28 shows the time series of the head for the first aquifer layer for the Landschotse Heide for the year of 2018. The North calculation point (see Figure 4.28c) shows a smoother line than the South and Center calculation point (Figures 4.28a and 4.28b). This calculation point is located in the fir area on the North side of the Landschotse Heide. There are no waterways located nearby, which explains why the time series of this location is smoother. The head at this location does not react that fast on precipitation changes due to this lack of waterways. This is also why the difference in average Head is the biggest at this location.

The South calculation point (Figure 4.28a) is located close to a waterway resulting in a quicker head reaction after precipitation. This also explains why the difference between the average heads is the smallest at this location. The water is quickly drained by the waterways and discharged downstream.

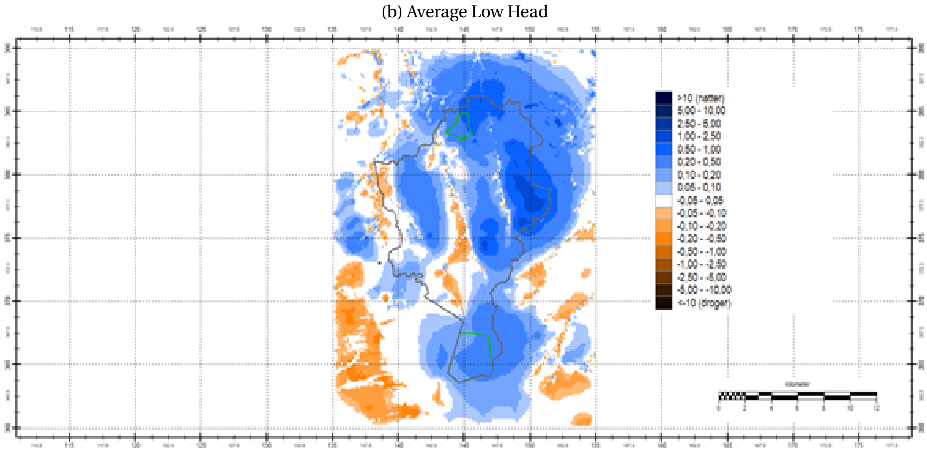
Figure 4.29 shows the time series of the head for the first aquifer layer for De Pielis for the year 2018. The shape of the head line for the "brook swamp" intervention does not differ from the BASE model. This is due to the thick sand layer at the location of De Pielis. Water quickly infiltrates through sand layers. The South-West calculation point (Figure 4.29a) has the smallest difference in average Head, because this location has the smallest drainage area upstream.



(a) Average High Head



(b) Average Low Head

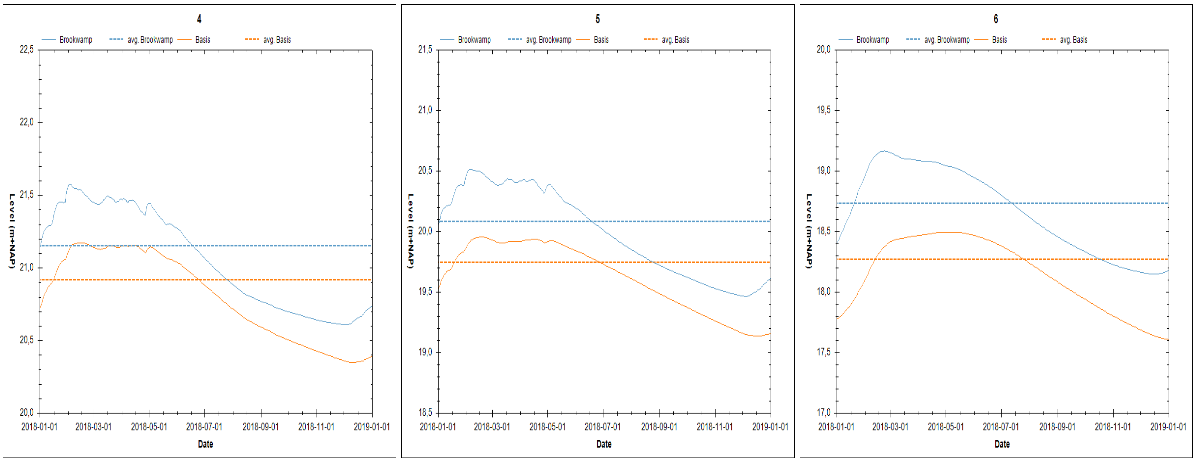


(c) Average Spring Head

Figure 4.27: Head difference for the "brook swamp" intervention compared to the BASE model for the non-stationary model (legend in $meters$, 'natter'=wetter, 'droger'=dryer, grey is the catchment area and green are the Landschotse Heide (top) and De Pielis (bottom) areas.

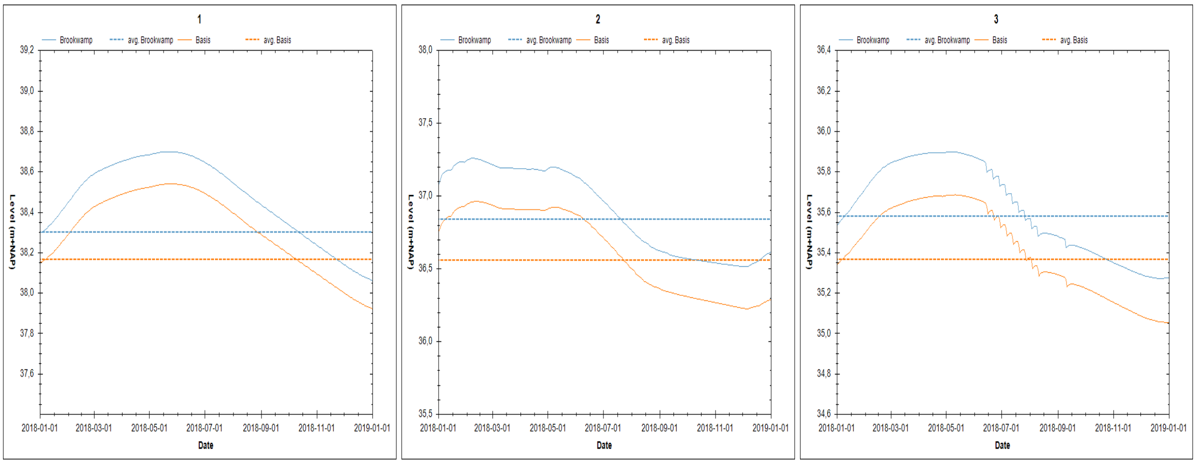
4.6. Comparison of results

In this section different results are compared. Firstly the results for the two areas are compared and linked to the characteristics of the two areas. After this the results for the stationary model are compared to the results of the non-stationary model.



(a) South calculation point (b) Centre calculation point (c) North calculation point

Figure 4.28: Time series of the head for the BASE model and the "brook swamp" intervention for the Landschotse Heide for the year 2018.



(a) South-West calculation point (b) Centre calculation point (c) North-East calculation point

Figure 4.29: Time series of the head for the BASE model and the "brook swamp" intervention for De Pielis for the year 2018.

4.6.1. Difference per area

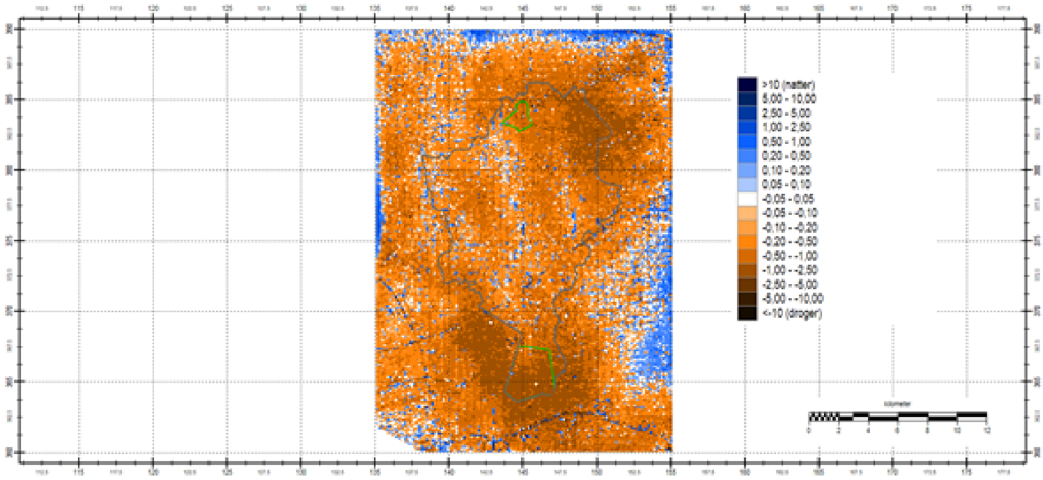
What can be seen is that at De Pielis area, which is located on a thick sand layer, changes in the top layer do not have a big effect on the head, water balance or flow paths. While at the Landschotse Heide, located more in the middle of the catchment with some clay layers close to the top layers, the effect of these changes is bigger. For the dryer climate scenarios De Pielis is really suffering with drought. Whereas the Landschotse Heide still has some seepage and river flow. For De Pielis, the abstraction scenarios have a bigger impact than at the Landschotse Heide, which might also be the result of the thick sand layer. Water is easily abstracted through this thick sand layer, affecting the water in the whole sand layer, all the way to the surface.

4.6.2. Difference stationary and non-stationary model

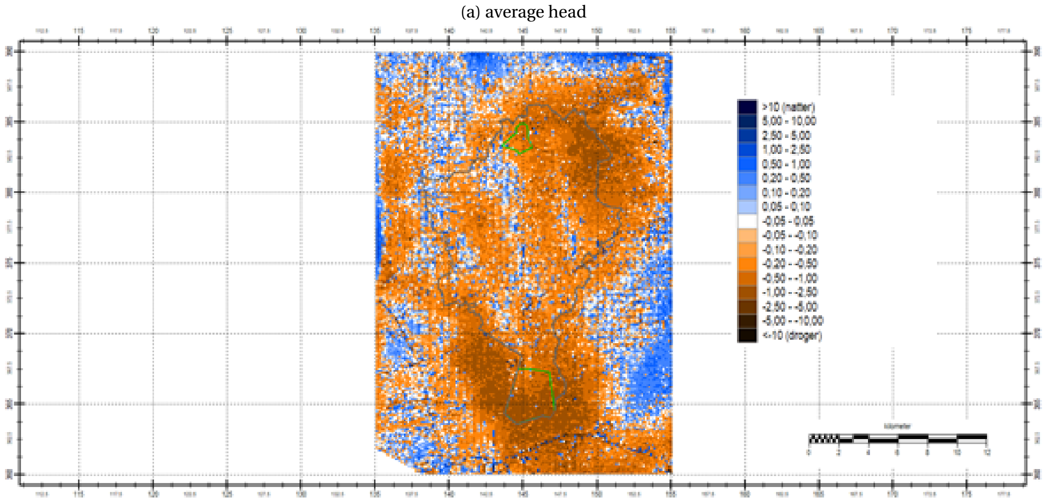
Figures 4.30, 4.31 and 4.32 show the differences in head for the non-stationary models compared to the stationary model for the year 2018. It can be seen that the non-stationary model generates a lower head than the stationary model. It also shows that the average spring head (ASH) has more white spots and therefore corresponds more with the heads of the stationary model.

The areas focused on in this research show a big difference, also for the average spring head. The "brook swamp" intervention shows the most white spots indicating that the models for this intervention correspond better. Still a lot of areas are dryer or wetter in the non-stationary model.

The question therefore remains which model represents the reality best. Because there is a pattern in the over- or under-performance of the different models the relative difference for the heads might be comparable. With the relative difference for the head is meant the head differences within the stationary model (Section 4.2.1) and the head differences within the non-stationary model (Section 4.5.1). The head differences for the "brook swamp" intervention in the non-stationary model show better results than the head differences for this intervention in the stationary model. This indicates that for this intervention it is better to use the non-stationary model than the stationary model.

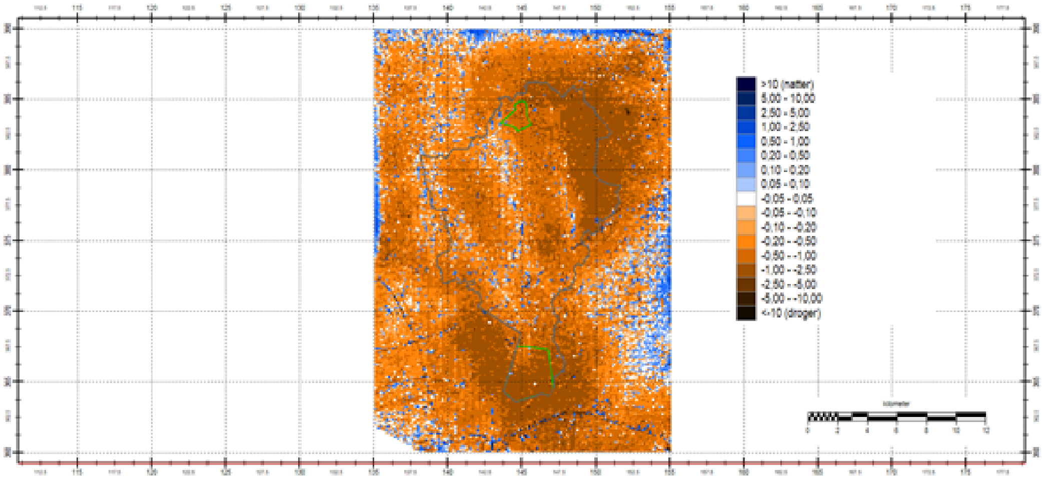


(a) average head

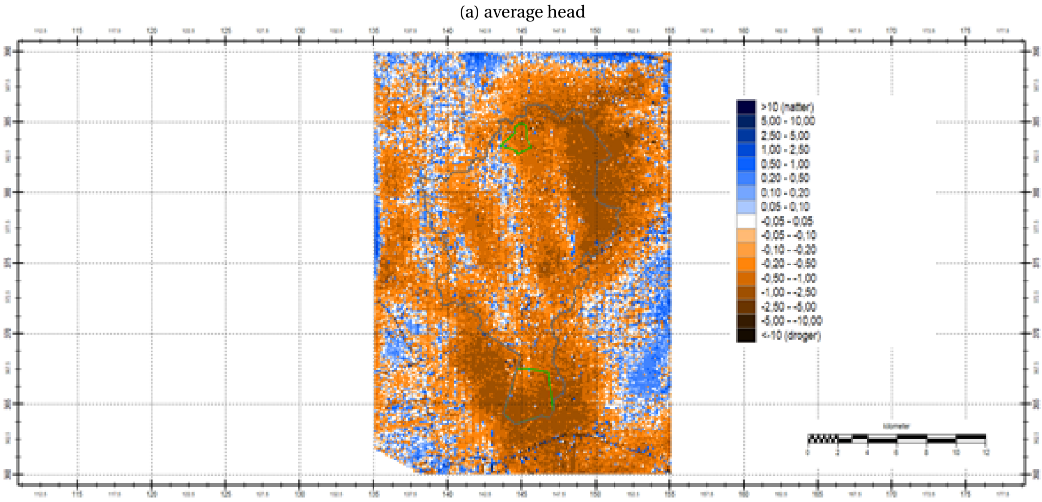


(b) average spring head

Figure 4.30: Difference for the average head of the non-stationary BASE model and the head of the stationary BASE model, both for the year 2018 (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

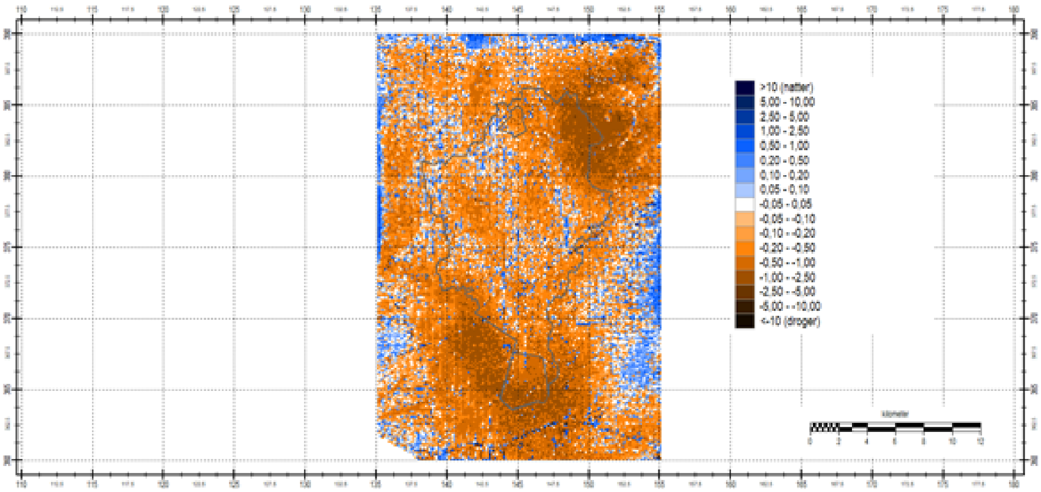


(a) average head

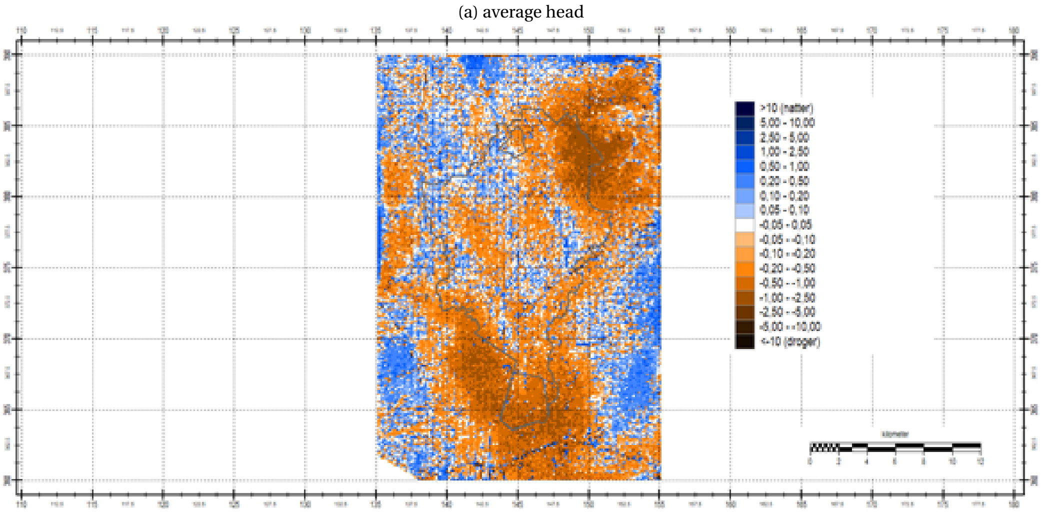


(b) average spring head

Figure 4.31: Difference for the average heads of the non-stationary model with infiltration factor 0.3 and the head of the stationary model with infiltration factor 0.3, both for the year 2018 (legend in $meters$, 'natter'=wetter, 'droger'=dryer).



(a) average head



(b) average spring head

Figure 4.32: Difference for the average heads of the non-stationary model and the head of the stationary model for the "brook swamp" intervention, both for the year 2018 (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

5

Conclusion & Discussion

5.1. Conclusion

The research question for this research was: 'How does the groundwater of two different areas within Waterschap De Dommel react to different interventions to prevent water shortage in long-term future scenarios?' The answer to this question is that the groundwater reacts differently per area as well as per intervention. The groundwater reacts less positive to the interventions at De Pielis area than at the Landschotse Heide area. The "higher water level" and "closed ditches" interventions result in the most positive reactions of the groundwater in both areas. In the following paragraphs this answer is substantiated and elaborated.

Tables 5.1 and 5.2 give an overview of the results of the different interventions for the Landschotse Heide and De Pielis, respectively. From this it can be concluded that for De Pielis area interventions in the top soil do not have (much) effect on the water availability for the area itself. The flow paths do show, for some interventions, positive results for downstream areas. The results for the Landschotse Heide show more positive effects on the water availability. This is however only reached when the interventions are implemented in a big upstream area. Only implementing the interventions close by (like the "climate buffer" intervention) show limited positive results.

The abstraction scenarios give bigger changes in head, water balance and flow paths for De Pielis as well as the Landschotse Heide area. Also the "agricultural abstraction" estimation shows the possible impact of groundwater abstraction from agriculture. If the Water Board wants to tackle water shortage, changing the water abstraction will have more impact than the interventions in the top aquifer layer.

When looking at both areas and all climate scenarios the intervention "closed ditches" works best. This intervention also results in overland flow, more in the wetter climate scenarios than for the dryer climate scenarios. If this overland flow can be captured this intervention might even have a bigger positive effect. For the wetter climate scenarios this overland flow can become too much and result in nuisance for farmers or residents in De Pielis area. In the Landschotse Heide area this should not be a problem.

The head differences and time-series of the non-stationary model show a positive effect of the "brook swamp" intervention. They show a bigger positive effect than the different signals of the stationary model. This indicates that for an intervention which is expected to have different results depending on the season, like a brook swamp, a non-stationary model is required.

The columns History and System analysis in the tables are based on historical maps and expert judgement. Some interventions can be found in the historical maps and can therefore be seen as effective interventions. Based on the system analysis in this research a column is added for the expected results on the reaction of the groundwater to the different interventions.

To conclude: this research shows that some interventions work in different climate scenarios and could therefore be used to tackle water shortage. However, this research also shows that these interventions are not

Table 5.1: Overview of results of the interventions for the Landschotse Heide

intervention	Head	Water table	Flow paths	History	System analysis	Head (non-stationary)	Head time-serie (non-stationary)
Higher water level	+++	+++	+++		++		
Brook swamp	-/+	+	++	+	+	++	++
Meandering	0	0	0	+	+		
Closed ditches	++	++	+	++	++		
Agricultural abstraction*	–	-	-	-	-		
Effluent infiltration	+	+	0		+		
Less mowing	++	+	+		+		
Climate buffer	+	-	+		++		
Higher water level + Closed ditches	+++	+++	+++	+	+++		
Climate buffer + Effluent infiltration	+	+	+		++		

*The agricultural abstraction is not an intervention to decrease water shortage but gives an estimation of the contribution of agricultural abstraction within the areas.

Table 5.2: Overview of results of the interventions for De Pielis

intervention	Head	Water table	Flow paths	History	System analysis	Head (non-stationary)	Head time-serie (non-stationary)
Higher water level	++	-	++		+		
Brook swamp	-	-	+	+	+	++	++
Meandering	0	-	0	+	+		
Closed ditches	+	0	++	+	+		
Agricultural abstraction*	–	–	-	-	-		
Effluent infiltration	+	-	+		+		
Less mowing	+	-	0		+		
Climate buffer	0	0	0		0		
Higher water level + Closed ditches	+++	++	+	+	++		
Climate buffer + Effluent infiltration	0	+	-		0		

*The agricultural abstraction is not an intervention to decrease water shortage but gives an estimation of the contribution of agricultural abstraction within the areas.

equally effective for both research areas. The results of the interventions are dependent on the geohydrological conditions as well as the land-use and location in the catchment. With this research a foundation is formed for adaptation pathways to help with long term policy analysis.

5.2. Discussion

For structure the discussion has been divided into three subsections: the discussion about this research, a discussion about, and recommendations for, follow-up research and recommendations for the Water Board based on this research.

5.2.1. This research

As mentioned in the methodology chapter there are some assumptions made in this research. The agricultural abstraction is a big unknown in this research as well as for the Water Board. In the results of this research it can be seen that this can have a big impact on the water availability in the areas. These results are however based on the assumption that all agricultural land needs groundwater abstraction during the agricultural season. Also the assumed abstractions are only modelled for the two areas in this research, so abstractions for other agricultural areas within De Dommel are not included in the model. This means that there is possibly even less water available than the results of the model.

Another difficulty in this model is the area of De Pielis. This is located at the border with Belgium, where different kinds of data are gathered. This had to be adjusted to the data needed for the model. Also less data for the area of Belgium is available, the B- and C-waterways are for example not included in the model. These differences make it difficult to model this area. Next to that the model border is close to De Pielis area. At this model border some parameters have a fixed value, otherwise the model cannot function properly. These parameters are not fixed in reality, making the model less accurate. This problem can be tackled by putting the model border further away from De Pielis. This however also increases the amount of data used within the area of Belgium.

Next to this big gap in data the results for the interventions should be used with care. Because the B- and C-waterways, and some A-waterways, are not submerged with water throughout the whole year the infiltration factor is set to 0 for the BASE models and the interventions (except for the "brook swamp" intervention). This was copied from the model of Water Board De Dommel where they use it to represent the reality better. In reality however, the waterways do have an infiltration factor but are not always discharging water. The positive results for the interventions where the water level is changed might therefore be overestimated. This problem can be tackled using the non-stationary model and changing the water level in the waterways every day, instead of seasonally. Setting up such a model however takes more time.

Another overestimation is the evaporation used for the model. In this model the reference evaporation is used instead of the real evaporation. The real evaporation would take to much time to generate with all the different land-uses and crops within the area of De Dommel. The reference evaporation is an overestimation. Therefore the results will also be an overestimation, meaning they will give a dryer result, which is the worst-case scenario for this research.

Next to these assumptions a model is always a simpler version of reality, resulting in an outcome of the model which will never be the reality (Oreskes et al., 1994). Besides that, the model has not been validated properly because most of the input data used was taken from the Water Board which they have been using for their model. For the non-stationary model more data was needed which was extracted from other models within Sweco, which also have not been validated properly within this research. Validating the model might give more realistic results.

Due to the many assumptions expert judgement is crucial when using models like the one used in this research. The following question can therefore be asked: Does a model like this give more insight in the working of interventions than only expert judgement? And if so, is it worth all the troubles a model gives?

For a person outside the area of Water Board De Dommel, with little knowledge about the area and how the system works, the stationary model already gives a better insight. Modelling the (combined) interventions can be an added value to expert judgement but might not be necessary. In this research only the "brook swamp" intervention gave a different result with the stationary model than was expected. Also the relative difference of positive results for each intervention can be predicted with expert judgement. The model can therefore have a supporting function for the expert judgement, but is not necessary.

During this research it was a nuisance to set up the model and to produce the flow path results. The time spent to set-up the model or waiting for the results to load can also be used to improve the expert judgement or for field research when more insight in the system is desired. The non-stationary model takes even more time to set-up and run, making it a bigger nuisance to work with. For future modeling studies it is important to consider how much work is needed to set-up the model.

5.2.2. Follow-up research

The non-stationary model can give a better, more detailed, insight in how the system works seasonally and changes in precipitation patterns can be included. Predictions for future precipitation patterns show longer dry periods and heavier precipitation within smaller time frames. This must have an effect on the water system in the Netherlands and also in the area of Water Board De Dommel. Due to time restrictions this was not possible to include in this research but it can be of added value within a follow-up research.

Further follow-up research could include more interventions in the non-stationary model to compare with the results of the stationary model. This could give more insight in the added value of a non-stationary model, or even if there is an added value. Another follow-up research might be using only the non-stationary model and implementing interventions at different moments in time to see the effect of combinations and if these effects compliment each other.

In this research the flow paths are modeled with starting points within and surrounding the two research areas. This model is also able to model reverse flow paths, meaning it can trace back where the water comes from that ends up in the research areas. This might also be an added value for the Water Board, to locate where the source area is, to determine the area(s) where the interventions can be implemented. This also might increase the applicability of the interventions. Because implementing the interventions for the whole area of the Water Board is not realistic. For the implementation also the costs will play a big role, which is not investigated in this research.

Implementing these interventions can also create negative effects for agriculture, which is dependent on a specific water level in the waterways. When more water is stored inside agricultural areas this might mean that farmers have to switch to other crops which can cope better with wetter soils.

5.2.3. Recommendations for the Water Board

As mentioned above the agricultural abstractions are a white spot in the data and can have a big impact on the water availability. It is therefore recommended to investigate this abstraction in the whole area of De Dommel, resulting in better insight in water use and the effects it may have on the interventions and the water availability.

As can be seen in the Chapter results, interventions in the top layer do not have much effect for the subsoil at De Pielis. It does show small positive effects for the top layers, which might be beneficial for agriculture. If the top layers can be enriched with more nutrient-rich soils (like clay and silt) these top layers can hold this water even better. It is therefore recommended to investigate the potential of enriching the top layers.

For the Landschotse Heide area it is recommended to think about the priorities of the Water Board. The agricultural area around the Landschotse Heide cannot be cultivated in the same way as it is now when the Water Board wants to improve the Landschotse Heide area. This agricultural land needs to extensify when the interventions tested in this research are implemented.

A last remark should be made on the effects of climate change. Climate change will happen and cannot be prevented. Projections now are suggesting that the Netherlands might get a climate like the current climate in the Mediterranean (Snoek, 2020). This is a dryer climate than the current climate in the Netherlands. There is no visible trend in changes in precipitation, but there is a trend in increased temperature and therefore also in increased potential evaporation (KNMI, 2020). Interventions like the ones modeled in this research might postpone the effects of this trend but will not be able to prevent this trend and the effect it will have on the water availability (Van Loon & Van Lanen, 2013). Eventually all land-uses and water management will have to adapt to the new, dryer, climate. Agriculture will have to switch to drought-resistant crops and nature will change too. Trying to maintain the current standard is therefore a futile exercise.

Bibliography

Alterra, W. (2018). Lgn viewer - wur. https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/Environmental-Research/Faciliteiten-tools/Kaarten-en-GIS-bestanden/Landelijk-Grondgebruik-Nederland/lgn_viewer.htm

Didde, R. (2021). Nederland droogteland. Uitgeverij Lias.

Dommel, W. D. (2021). Meer water voor landschotse heide. https://www.dommel.nl/meer-water-voor-landschotse-heide

Dommel, W. D. (2022a). Dit doet ons waterschap. https://www.dommel.nl/dit-doet-ons-waterschap

Dommel, W. D. (2022b). Ondergrondgegevens: Grondwaterstand. https://www.dinoloket.nl/ondergrondgegevens

Dommel, W. D. (2022c). Onttrekkingsverbod. https://dommel.webgispublisher.nl/Viewer.aspx?map=Onttrekkingsverbod#

Eindhovensdagblad. (2008). Moddersloot moet droog gebied natter maken. https://www.ed.nl/overig/moddersloot-moet-droog-gebied-natter-maken~a3f1539f/

Eindhovensdagblad. (2020). 'help, de heide verdwijnt': Brandbrief over verdroging landschotse heide. https://www.ed.nl/kempen/help-de-heide-verdwijnt-brandbrief-over-verdroging-landschotse-heide~a1778817/?referrer=https%5C%3A%5C%2F%5C%2Fwww.google.com%5C%2F

Esri Nederland, A. (2021). Actueel hoogtebestand nederland. https://www.ahn.nl/ahn-viewer

Haasnoot, M., Middelkoop, H., Offermans, A., Beek, E. v., & Deursen, W. P. A. v. (2012). Exploring pathways for sustainable water management in river deltas in a changing environment. Climatic Change, 115, 795–819. https://doi.org/10.1007/s10584-012-0444-2

Huirne, J. (2020). 2020 bij 8 droogste jaren. https://www.weer.nl/nieuws/2020/2020-bij-8-droogste-jaren

IPCC, Pörtner, H.-O., Roberts, D., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., & (eds.), B. R. (2022). Climate change 2022: Impacts, adaptation, and vulnerability. contribution of working group ii to the sixth assessment report of the intergovernmental panel on climate change (tech. rep.). Cabridge Universyt Press. In Press.

Kang, M., Kwon, H.-j., Lim, J.-H., & Kim, J. (2009). Understory evapotranspiration measured by eddy-covariance in gwangneung deciduous and coniferous forests. Korean Journal of Agricultural and Forest Meteorology, 11(4), 233–246.

Klimaatadaptatie, K. (2022a). Droogte. https://klimaatadaptatienederland.nl/thema-sector/droogte/

Klimaatadaptatie, K. (2022b). Uitzakken grondwaterstand. https://klimaatadaptatienederland.nl/stresstest/bijsluiter/droogte/basisinformatie/uitzakken-grondwaterstand/#h0477aae3-2423-492b-a718-f46d3175d86e

KNMI. (2014). Knmi '14: Climate change scenarios for the 21st century - a neherlands perspective; by bart van den hurk, peter siegmund, albert klein tank (eds), jisk attema, alexander bakker, jules beersma, janette bessembinder, reinout boers, theo brandsma, henk van den brink, sybren drijfhout, henk eskes, rein haarsma, wilco hazeleger, rudmer jilderda, caroline katsman, geert lenderink, jessica loriaux, erik van meijgaard, twan van noije, geert jan van oldenborgh, frank selten, pier siebesma, andreas sterl, hylke de vries, michiel van weele, renske de winter and gerd-jan van zadelhoff (tech. rep.). Scientific report WR2014-01, KNMI, De Bilt, The Netherlands. https://www.climatescenarios.nl

KNMI. (2019). Klimaatfluctuaties. https://www.knmi.nl/over-het-knmi/nieuws/klimaatfluctuaties

KNMI. (2020). Droogte. https://www.knmi.nl/over-het-knmi/nieuws/vaker-droogte-in-het-binnenland

KNMI. (2022a). Droogte. https://www.knmi.nl/kennis-en-datacentrum/uitleg/droogte

KNMI. (2022b). Neerslagtekort-droogte. https://www.knmi.nl/nederland-nu/klimatologie/geografische-overzichten/neerslagtekort_droogte

Krause, E. (2005). Fluid mechanics i. Springer.

landschap, B. (2017). Aanpak landschotsche heide. https://www.brabantslandschap.nl/actueel/werk-in-uitvoering/aanpak-landschotsche-heide/

Lempert, R. J., Popper, S. W., & Bankes, S. C. (2003). Shaping the next one hundred years: New methods for quantitative, long-term policy analysis. RAND Corporation. https://doi.org/10.7249/MR1626

Marchau, V. A. W. J., Walker, W. E., Bloemen, P. J. T. M., & Popper, S. W. (2019). Decision making under deep uncertainty : From theory to practice. Springer Nature. https://doi.org/10.1007/978-3-030-05252-2 natuurlijk kaptiaal, A. (2015). Beregeningsonttrekkingen: Locaties onttrekkingen uit grondwater en oppervlakte water. https://www.atlasnatuurlijkkapitaal.nl/kaarten

Noord-Brabant, P., Mol, A., & Geujen, C. (2007). Brabant waterland, watersystemen in beeld. Webwateratlas.

NOS. (2022). Waarschuwing voor duurder voedsel vanwege voorjaarsdroogte. https://nos.nl/artikel/2427461-waarschuwing-voor-duurder-voedsel-vanwege-voorjaarsdroogte

Oreskes, N., Shrader-Frechette, K., & Belitz, K. (1994). Verification, validation, and confirmation of numerical models in the earth sciences. Science, 263(5147), 641–646. https://www.science.org/doi/abs/10.1126/science.263.5147.641

Plaatsengids. (2020). De pielis. https://www.plaatsengids.nl/de-pielis

places, B. (2020). Landschotse heide. https://www.birdingplaces.eu/en/birdingplaces/netherlands/landschotse-heide

Rijkswaterstaat. (2021). Waterstaatskaarten / 1872 waterstaatskaart eerste editie. http://www.wildernis.eu/chart-room/?nav0=Waterstaatskaarten&nav1=1872%5C%20Waterstaatskaart%5C%20eerste%5C%20editie

Rijkswaterstaat. (2022). Droogte. https://www.rijkswaterstaat.nl/water/waterbeheer/droogte-en-watertekort

Snoek, A. (2020). Nederland krijgt een mediterraan klimaat. https://www.weerplaza.nl/weerinhetnieuws/klimaat/%5C%E2%5C%80%5C%98nederland-krijgt-een-mediterraan-klimaat%5C%E2%5C%80%5C%99/6304/

Stuurman, R., Verhagen, F., van Wachtendonk, A., & Runhaar, H. (2020). Een verkenning naar de watervraag van de noord-brabantse natuur (tech. rep.). Deltares, Royal HaskoningDHV, and Ecogroen.

Swift Jr., L. W., Swank, W. T., Mankin, J. B., Luxmoore, R. J., & Goldstein, R. A. (1975). Simulation of evapotranspiration and drainage from mature and clear-cut deciduous forests and young pine plantation. Water Resources Research, 11(5), 667–673.

Tannehill, I. R. (1947). Drought, its causes and effects. Princeton University Press.

Today, N. (2021).
het lijkt intussen meer een steppelandschap dan een heidegebied". https://www.naturetoday.com/intl/nl/nature-reports/message/?msg=27554

Van Loon, A. F., Gleeson, T., Clark, J., van Dijk, A. I. J. M., Stahl, K., Hannaford, J., Di Baldassarre, G., Teuling, A. J., Tallaksen, L. M., Uijlenhoet, R., Hannah, D. M., Sheffield, J., Svoboda, M., Verbeiren, T., B. Wagener, Rangecroft, S., Wanders, N., & Van Lanen, H. A. J. (2016). Drought in the anthropocene. Nature Geoscience, 9, 89–91. https://doi.org/10.1038/ngeo2646

Van Loon, A. F., & Van Lanen, H. A. J. (2013). Making the distinction between water scarcity and drought using an observation-modeling framework. Water Resources Research, 49, 1483–1502. https://doi.org/10.1002/wrcr.20147

Visitoirschot. (2021). Landschotse heide. https://visitoirschot.nl/vermelding/landschotse-heide/

Wilhite, D. A., & Glantz, M. H. (1985). Understanding: The drought phenomenon: The role of definitions. Water International, 10(3), 111–120. https://doi.org/10.1080/02508068508686328

A

Background information

In this chapter some pictures are shown to give a better view of the areas researched in this report.

Figure A.1: Weir of De Dommel in the Goorloop in De Pielis area.

Figure A.2: Landschotse Heide after a week of rain (7 October 2021).

Figure A.3: Downstream part of the Goorloop after a week of rain (7 October 2021).

Figure A.4: The Goorloop upstream of the previous picture after a week of rain (7 October 2021). One of the weirs of the Goorloop is also visible.

Figure A.5: A B-watercourse which drains into the Goorloop after a week of rain (7 October 2021).

B

Model results

B.1. Heads

In this section the head differences for the interventions not shown in the report are shown. The head differences are the heads of the interventions layer compared to the head of the BASE model for the first aquifer.

B.1.1. Single interventions

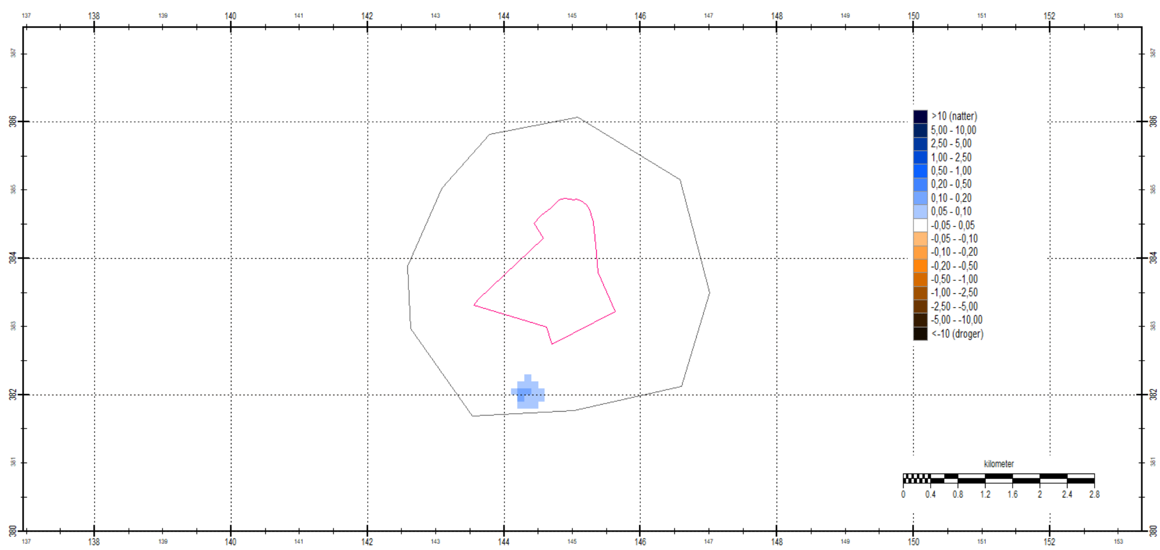


Figure B.1: Head difference for the Landschotse Heide and its surroundings for the Meandering intervention (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

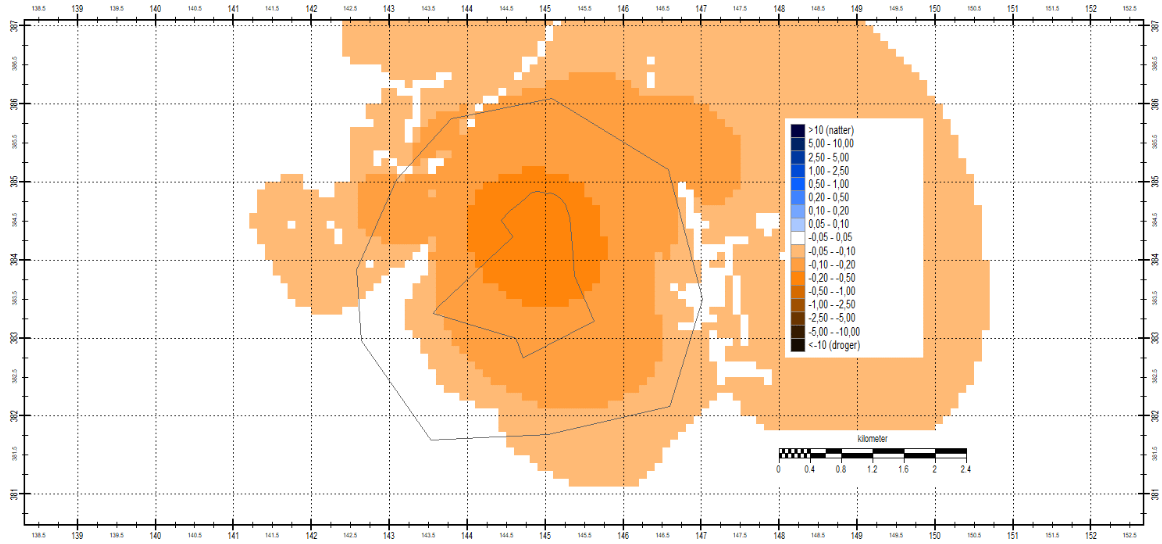


Figure B.2: Head difference for the Landschotse Heide and its surroundings for the Agricultural abstraction intervention (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

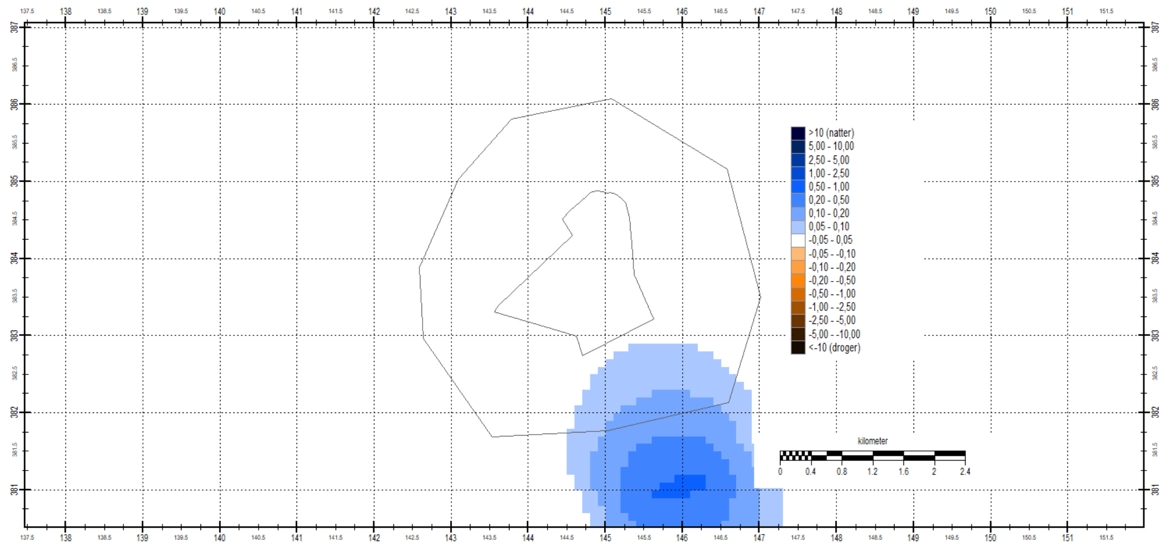


Figure B.3: Head difference for the Landschotse Heide and its surroundings for the Effluent infiltration intervention (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

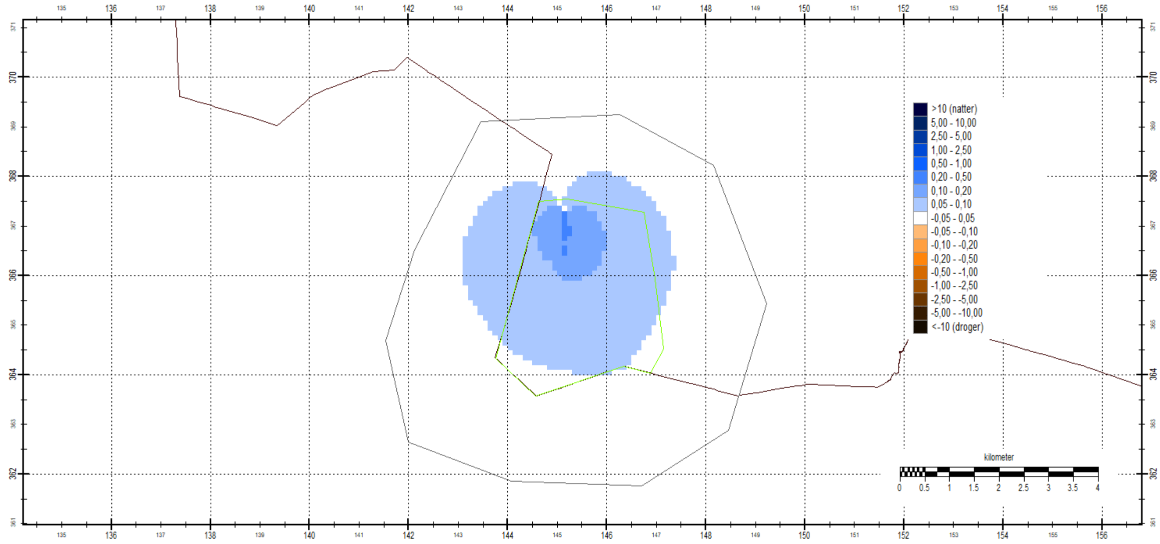


Figure B.4: Head difference for de Pielis and its surroundings for the Meandering intervention (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

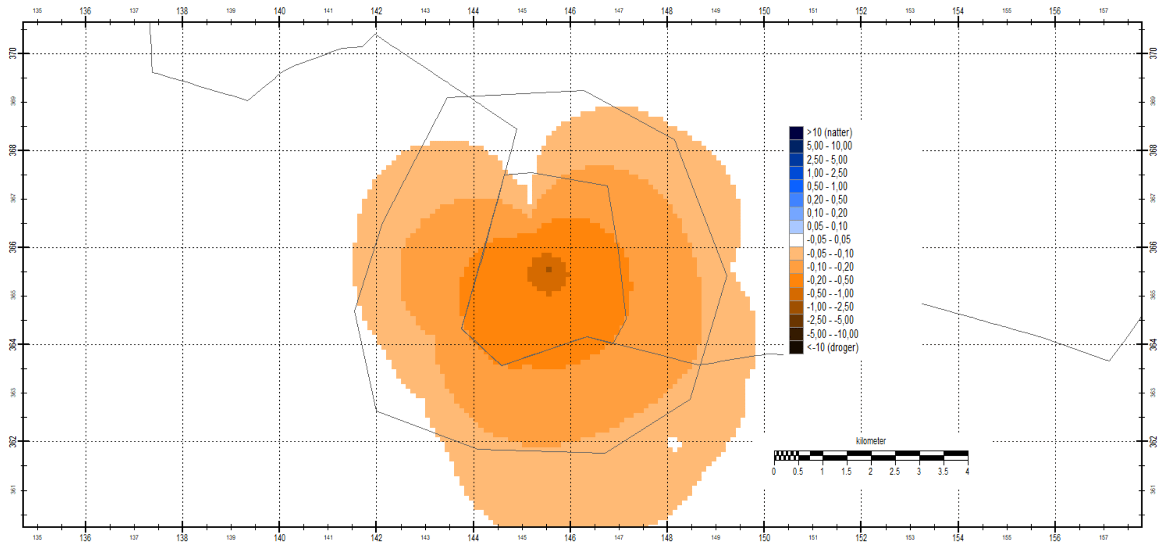


Figure B.5: Head difference for de Pielis and its surroundings for the Agricultural abstraction intervention (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

B.1.2. Climate scenarios with single intervention

Landschotse Heide

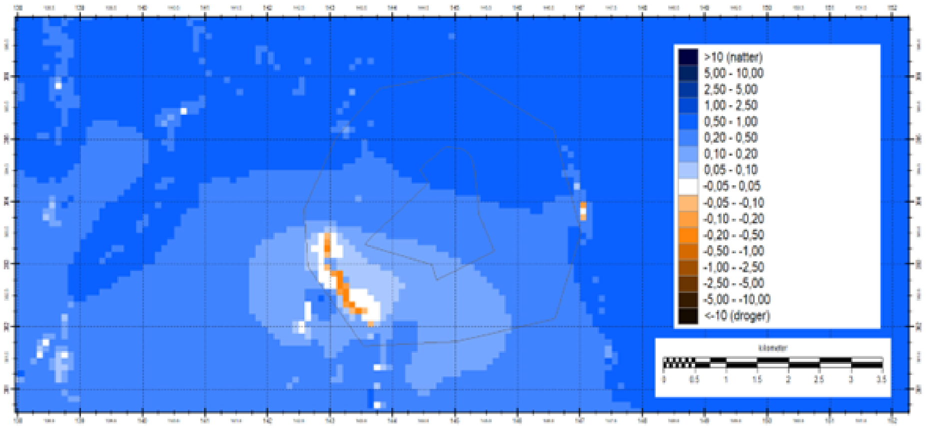


Figure B.6: Head difference for the Landschotse Heide and its surroundings for the "higher water level" intervention for the 2050GHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

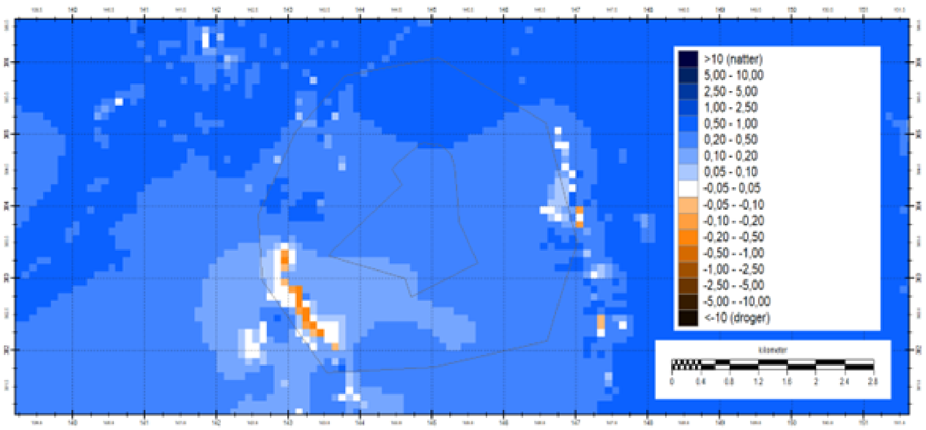


Figure B.7: Head difference for the Landschotse Heide and its surroundings for the "higher water level" intervention for the 2050WLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

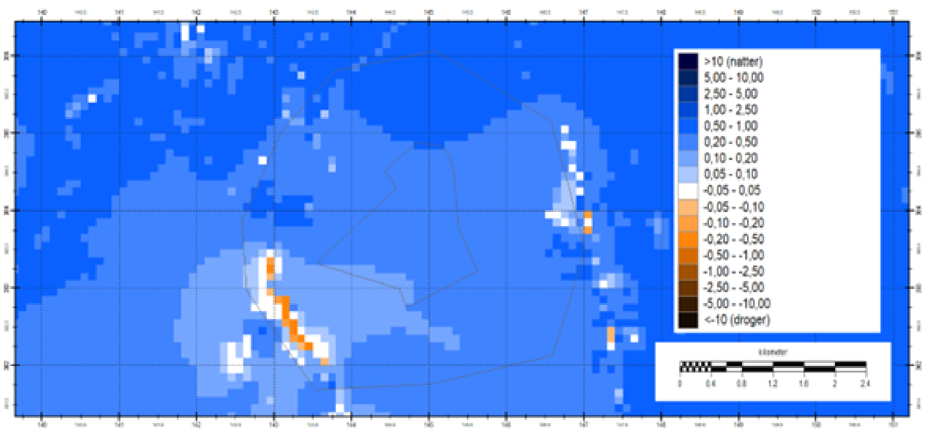


Figure B.8: Head difference for the Landschotse Heide and its surroundings for the "higher water level" intervention for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

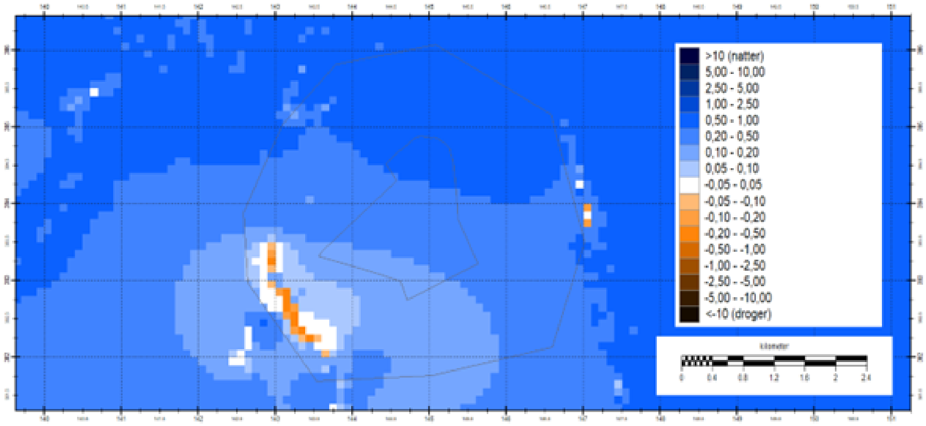


Figure B.9: Head difference for the Landschotse Heide and its surroundings for the "higher water level" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

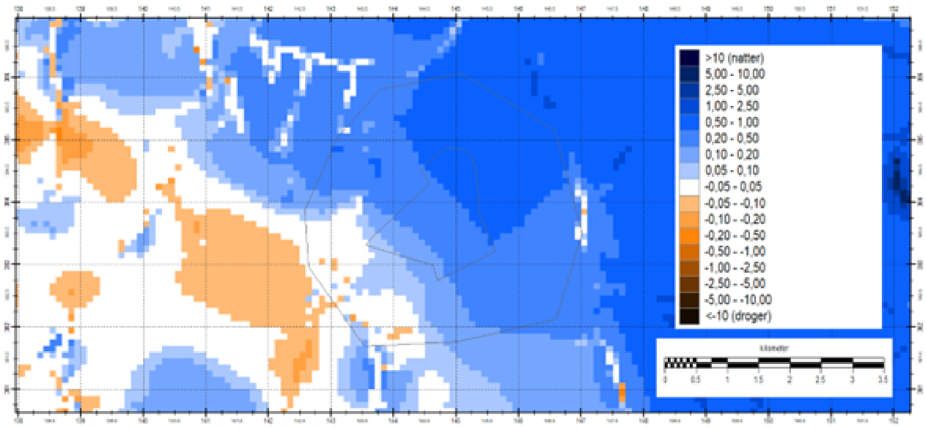


Figure B.10: Head difference for the Landschotse Heide and its surroundings for the "brook swamp" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

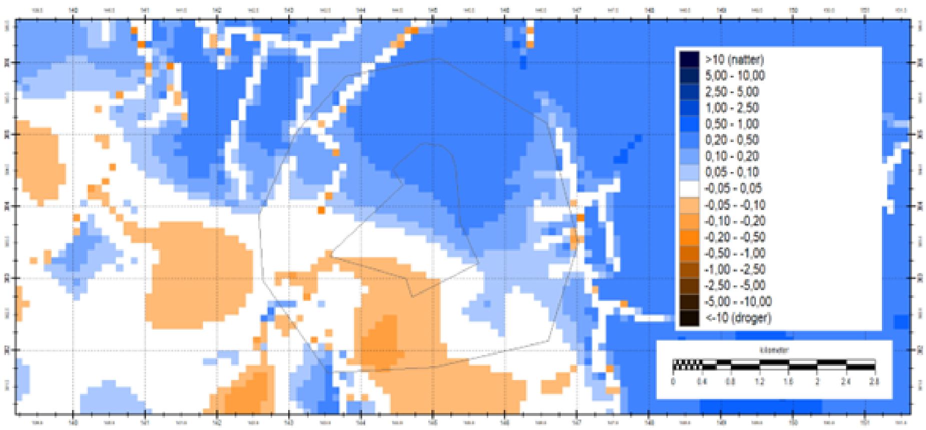


Figure B.11: Head difference for the Landschotse Heide and its surroundings for the "brook swamp" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

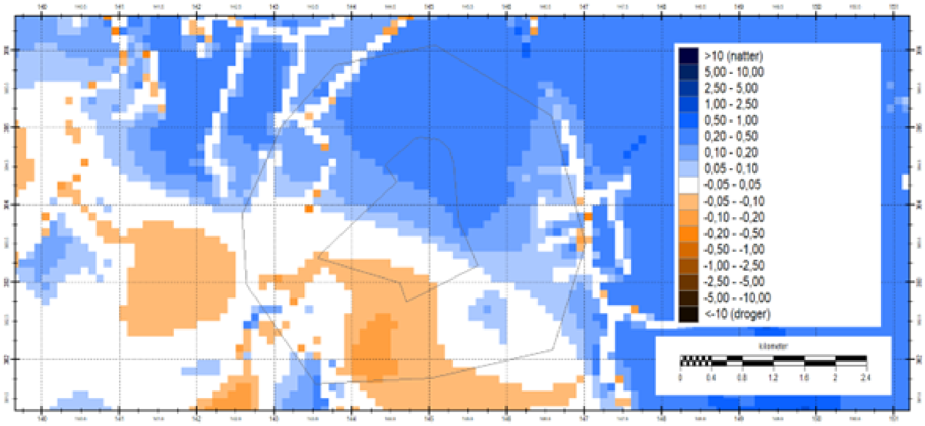


Figure B.12: Head difference for the Landschotse Heide and its surroundings for the "brook swamp" intervention for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

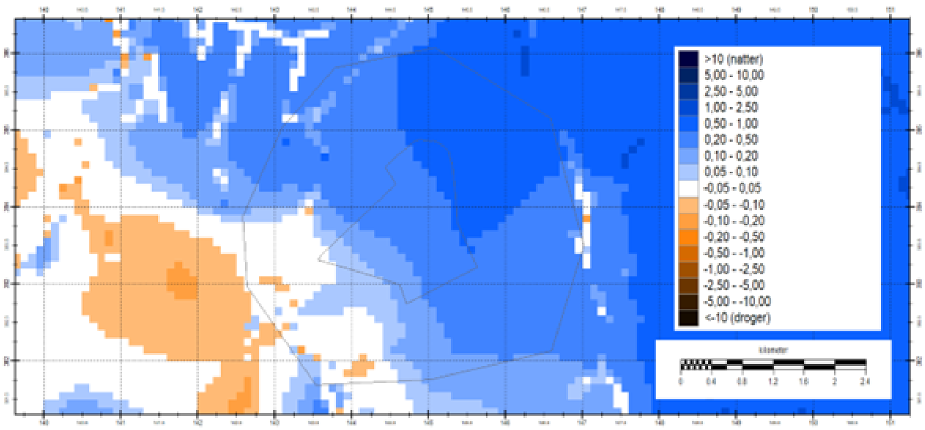


Figure B.13: Head difference for the Landschotse Heide and its surroundings for the "brook swamp" intervention for the 2085WHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

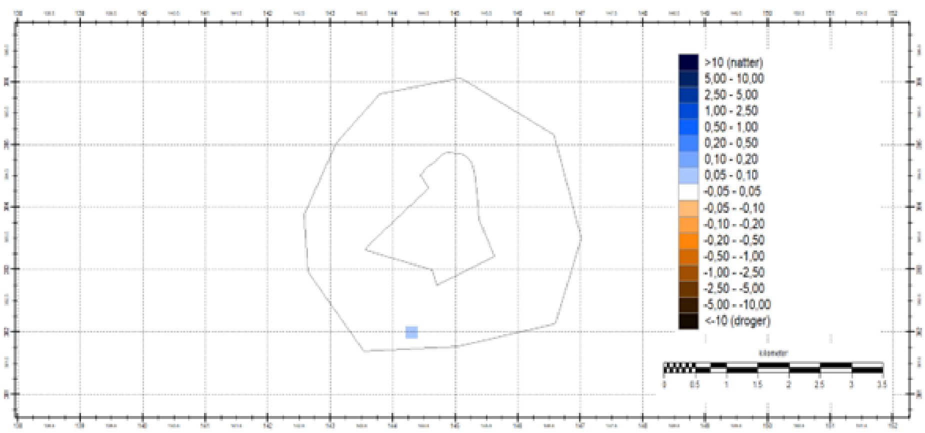


Figure B.14: Head difference for the Landschotse Heide and its surroundings for the "meandering" intervention for the 2050GHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

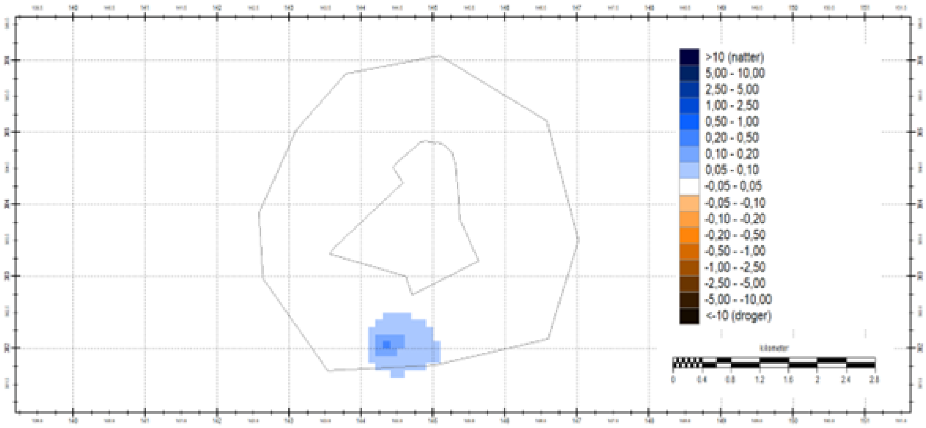


Figure B.15: Head difference for the Landschotse Heide and its surroundings for the "meandering" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

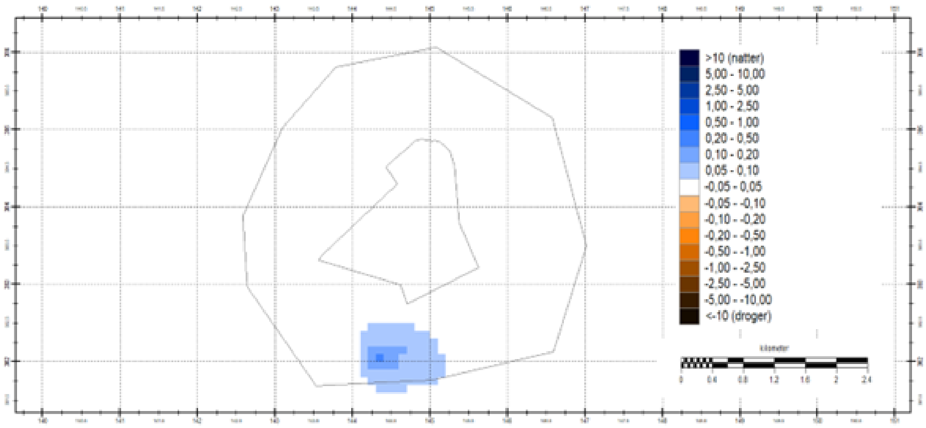


Figure B.16: Head difference for the Landschotse Heide and its surroundings for the "meandering" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

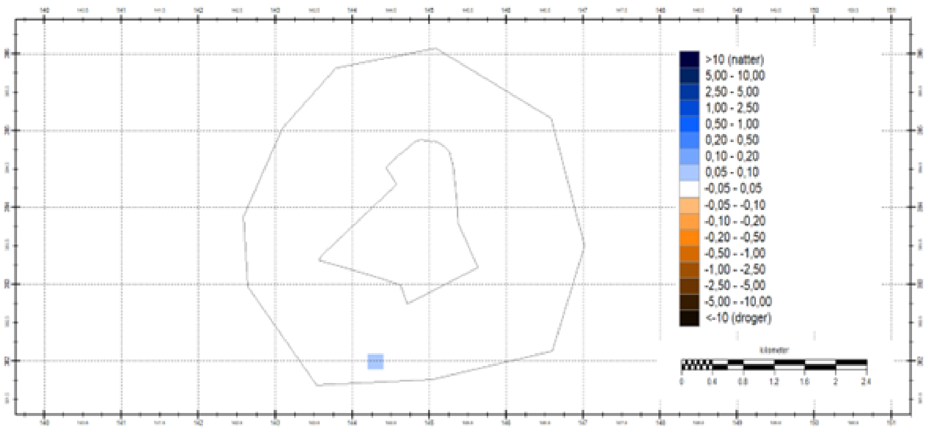


Figure B.17: Head difference for the Landschotse Heide and its surroundings for the "meandering" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

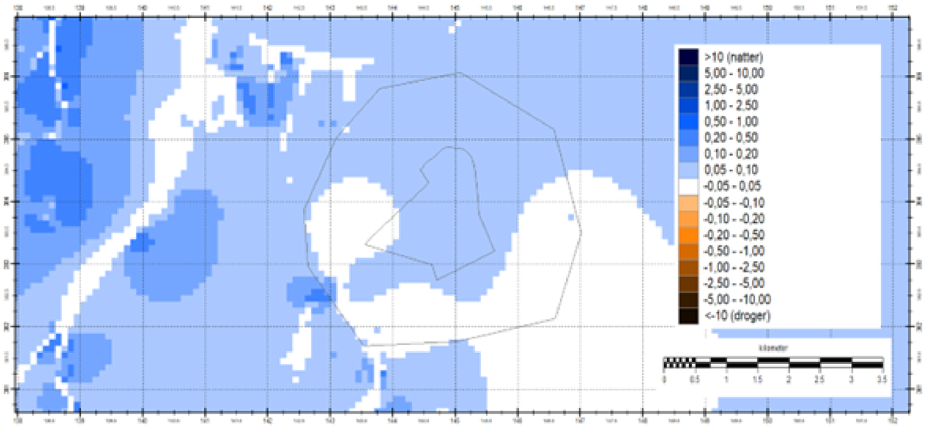


Figure B.18: Head difference for the Landschotse Heide and its surroundings for the "closed ditches" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

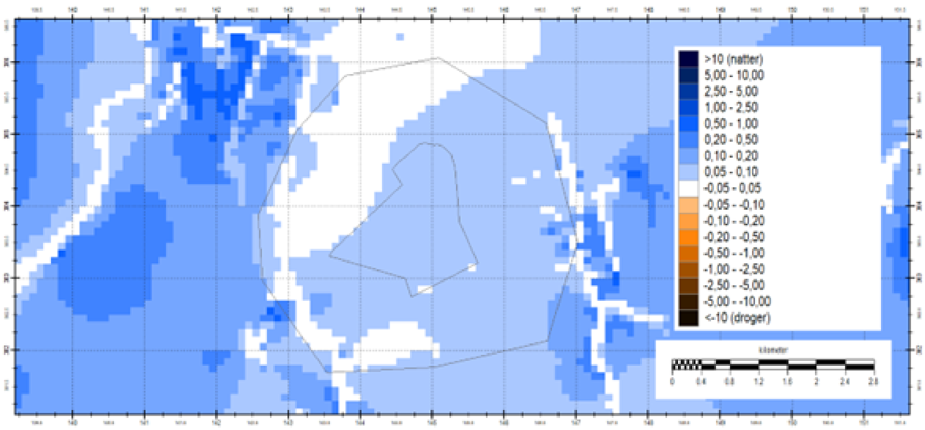


Figure B.19: Head difference for the Landschotse Heide and its surroundings for the "closed ditches" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

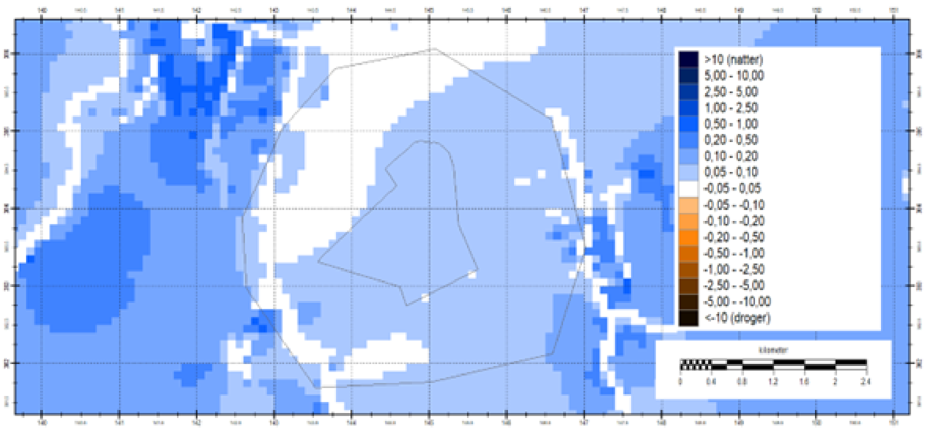


Figure B.20: Head difference for the Landschotse Heide and its surroundings for the "closed ditches" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

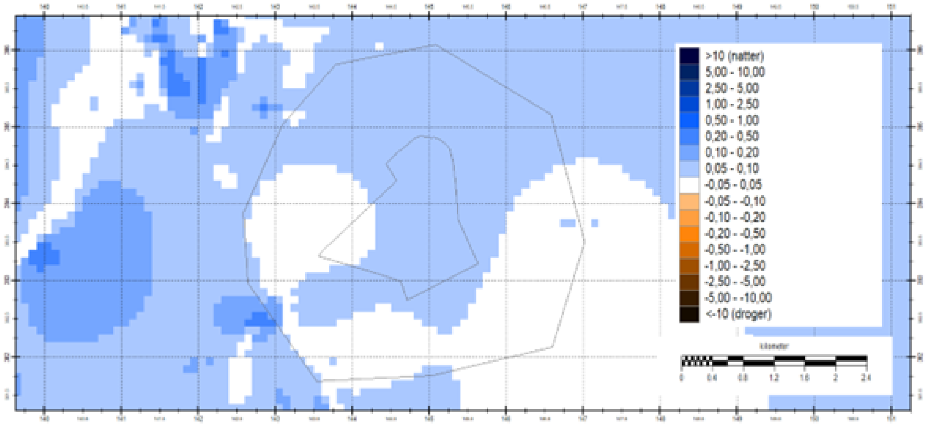


Figure B.21: Head difference for the Landschotse Heide and its surroundings for the "closed ditches" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

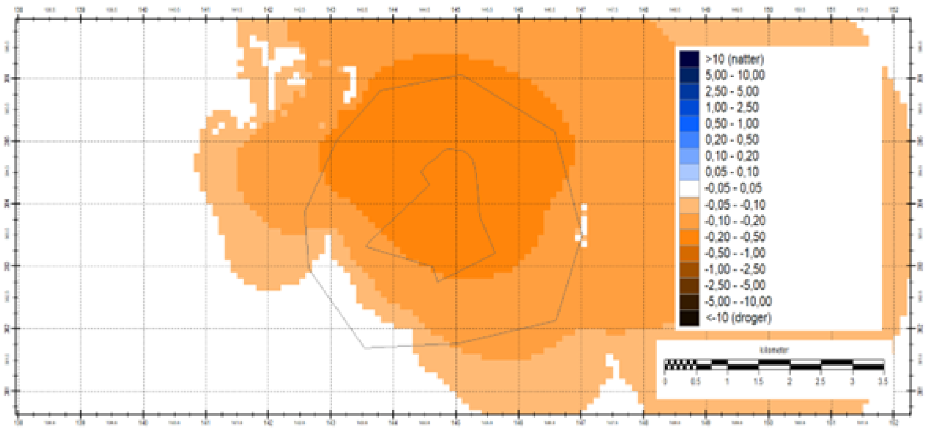


Figure B.22: Head difference for the Landschotse Heide and its surroundings for the "agricultural abstraction" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

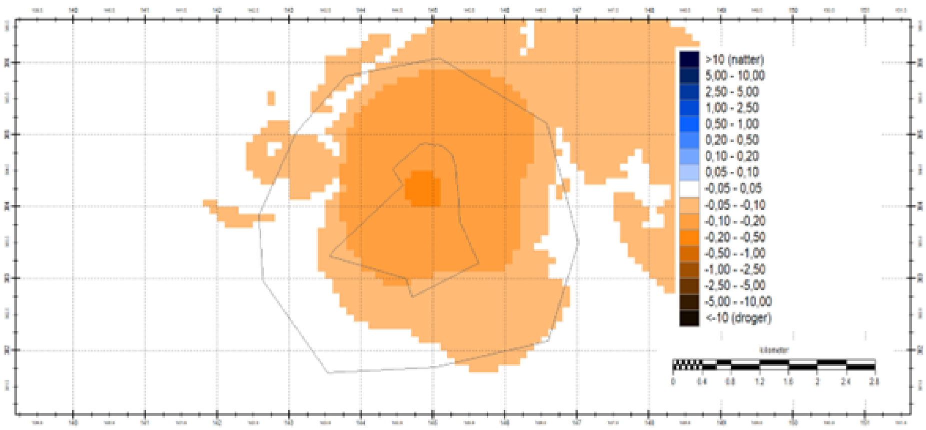


Figure B.23: Head difference for the Landschotse Heide and its surroundings for the "agricultural abstraction" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

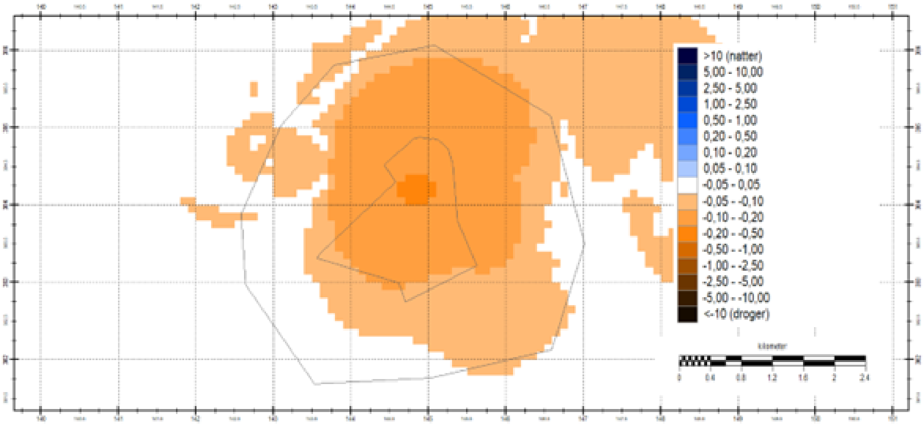


Figure B.24: Head difference for the Landschotse Heide and its surroundings for the "agricultural abstraction" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

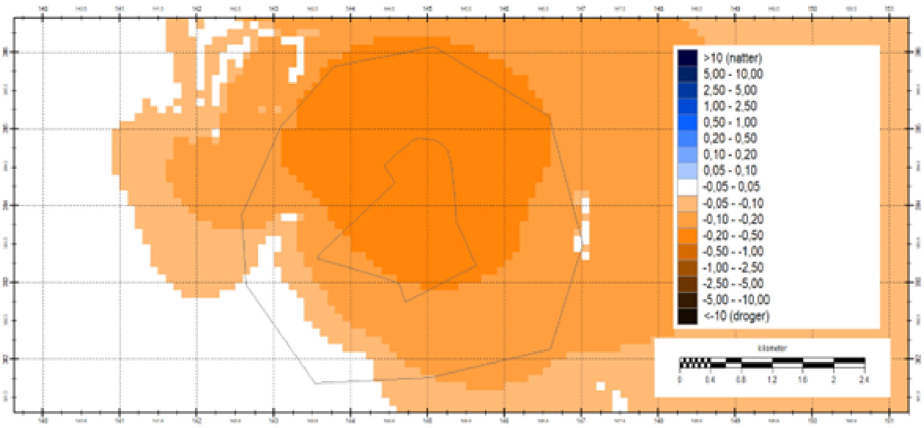


Figure B.25: Head difference for the Landschotse Heide and its surroundings for the "agricultural abstraction" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

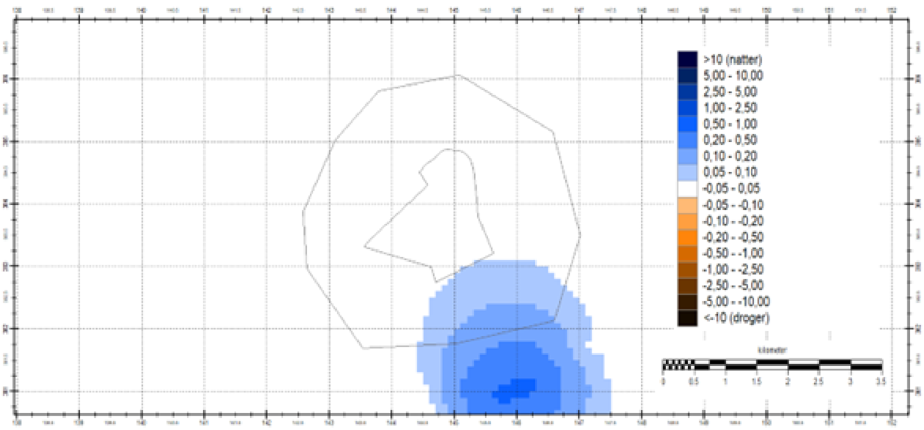


Figure B.26: Head difference for the Landschotse Heide and its surroundings for the "effluent infiltration" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

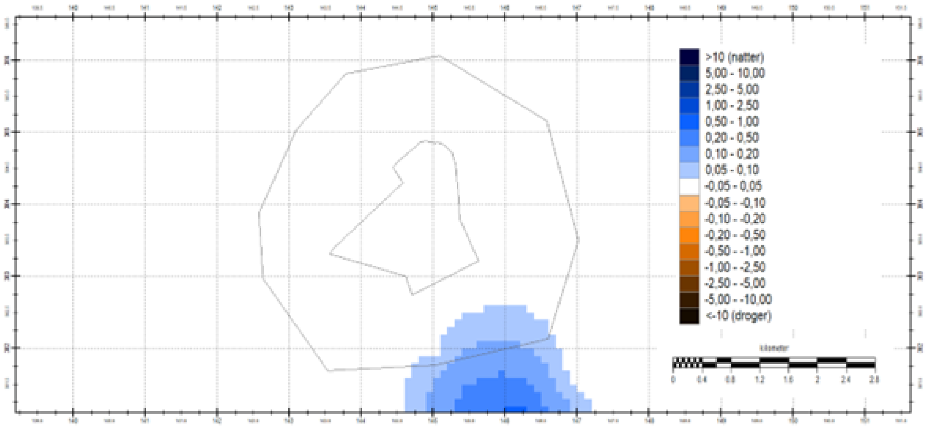


Figure B.27: Head difference for the Landschotse Heide and its surroundings for the "effluent infiltration" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

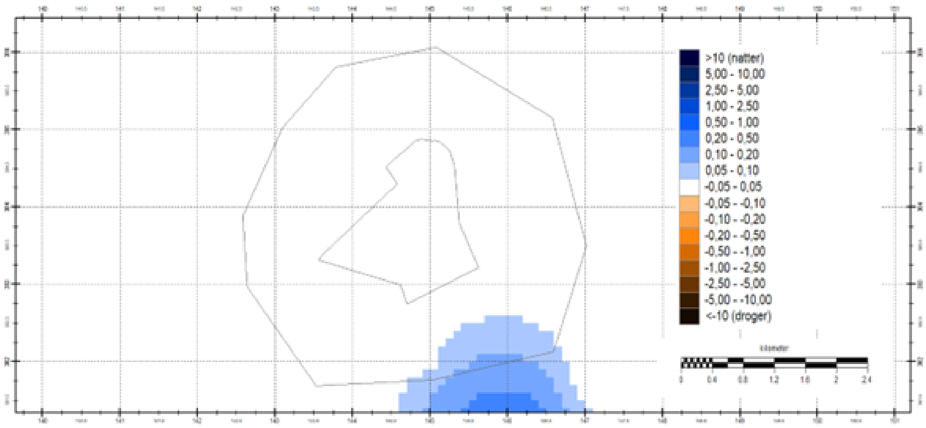


Figure B.28: Head difference for the Landschotse Heide and its surroundings for the "effluent infiltration" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

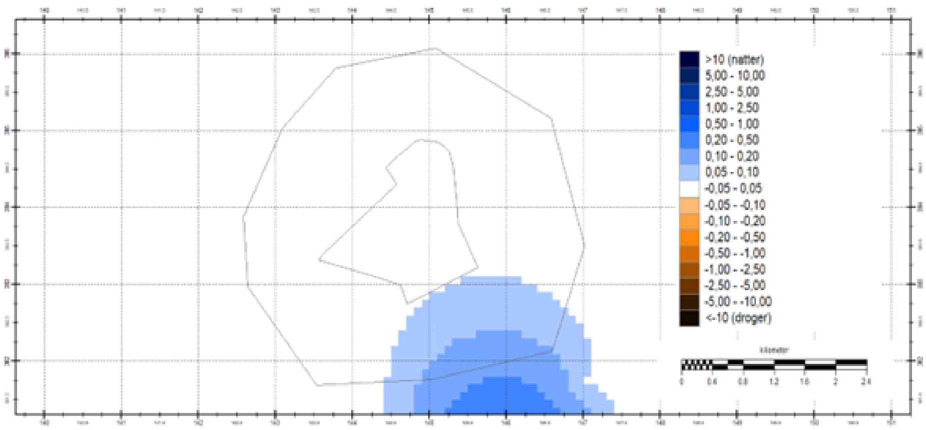


Figure B.29: Head difference for the Landschotse Heide and its surroundings for the "effluent infiltration" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

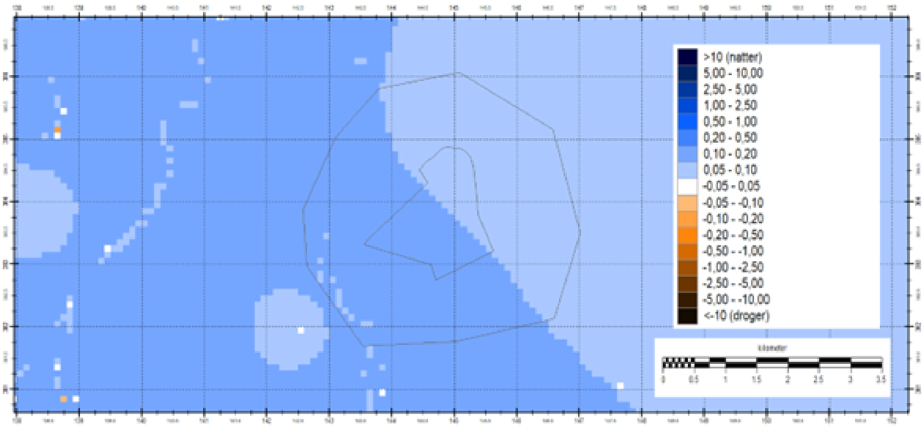


Figure B.30: Head difference for the Landschotse Heide and its surroundings for the "less mowing" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

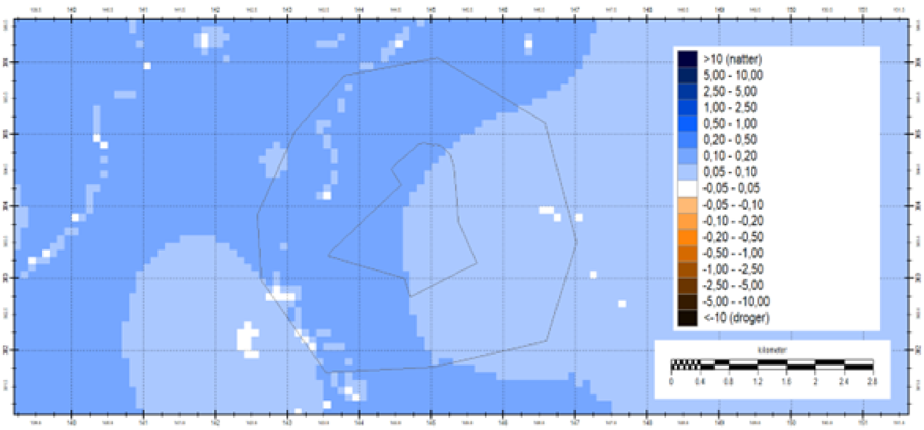


Figure B.31: Head difference for the Landschotse Heide and its surroundings for the "less mowing" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

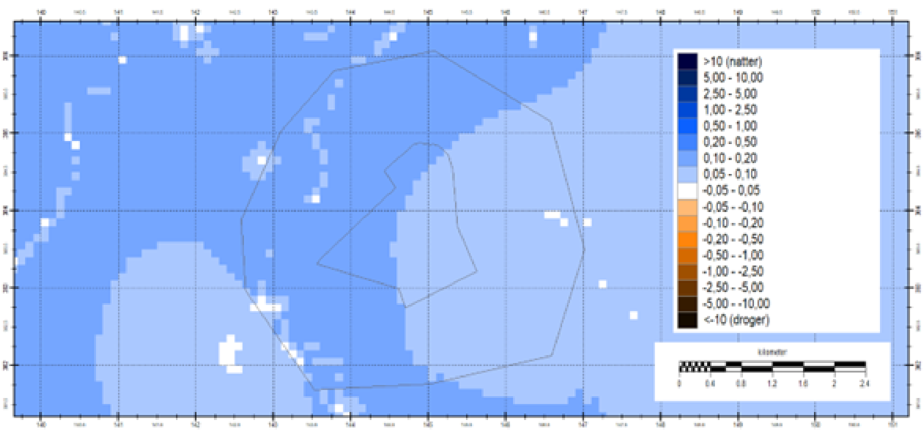


Figure B.32: Head difference for the Landschotse Heide and its surroundings for the "less mowing" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

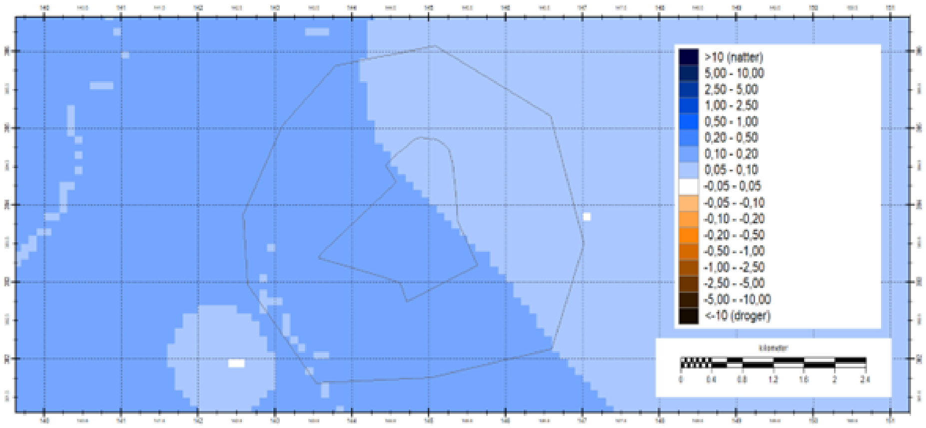


Figure B.33: Head difference for the Landschotse Heide and its surroundings for the "less mowing" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

De Pielis

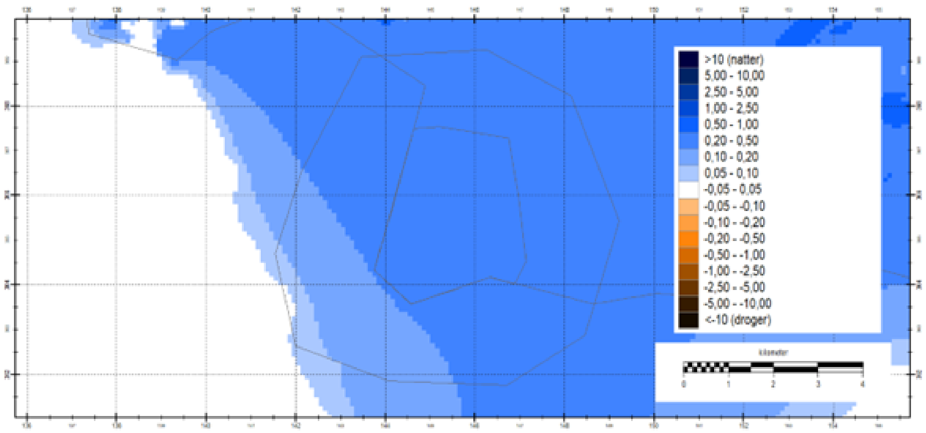


Figure B.34: Head difference for De Pielis and its surroundings for the "higher water level" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

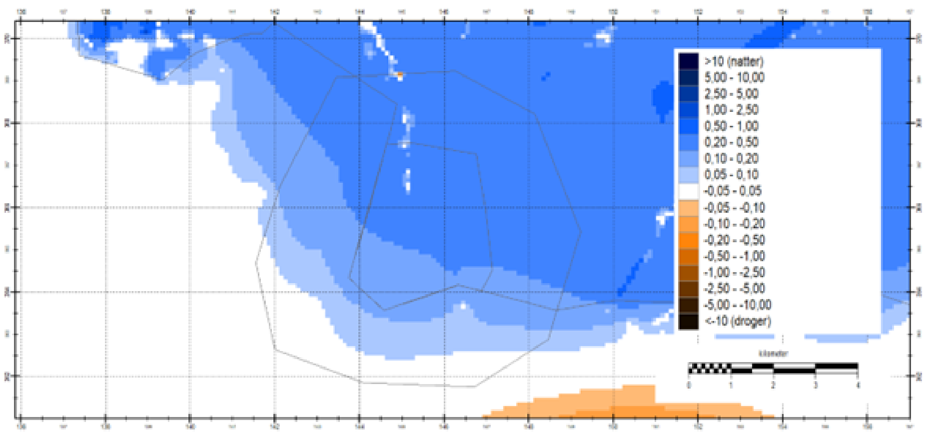


Figure B.35: Head difference for De Pielis and its surroundings for the "higher water level" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

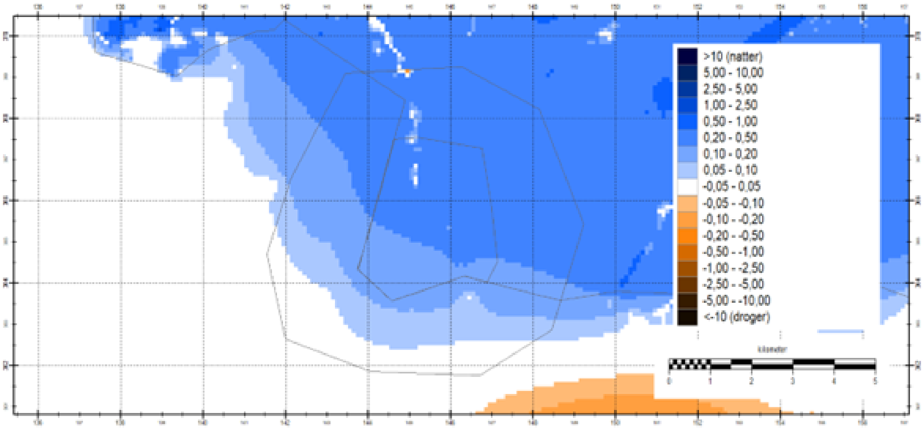


Figure B.36: Head difference for De Pielis and its surroundings for the "higher water level" intervention for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

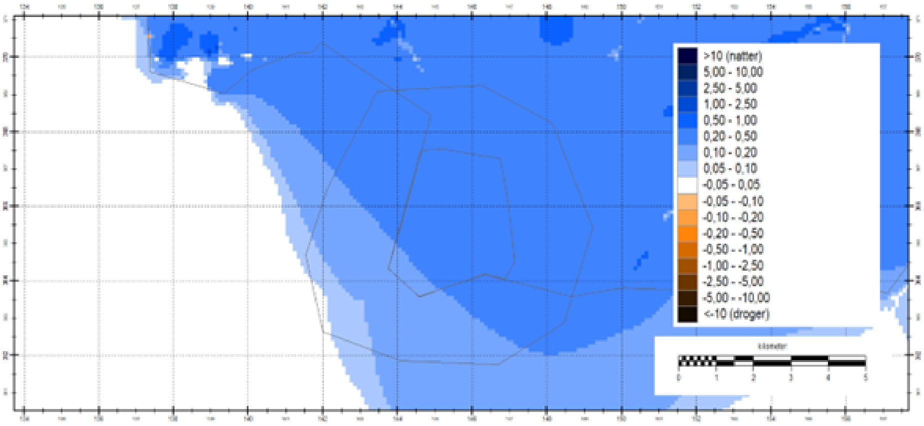


Figure B.37: Head difference for De Pielis and its surroundings for the "higher water level" intervention for the 2085WHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

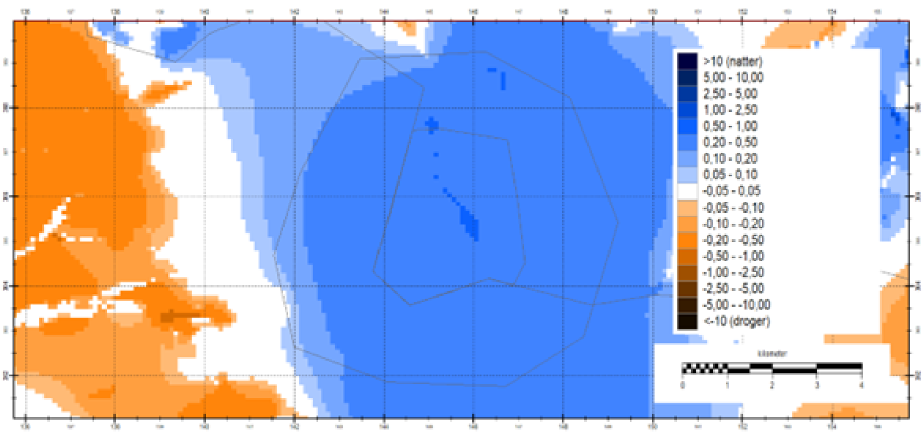


Figure B.38: Head difference for De Pielis and its surroundings for the "brook swamp" intervention for the 2050GHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

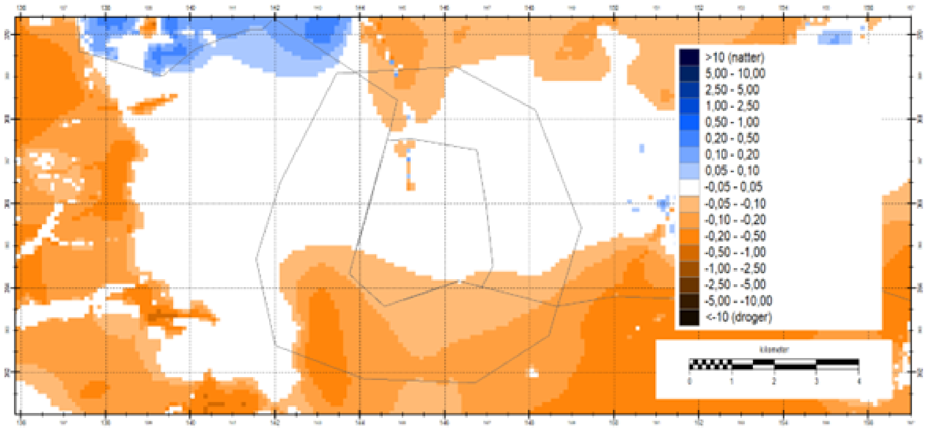


Figure B.39: Head difference for De Pielis and its surroundings for the "brook swamp" intervention for the 2050WLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

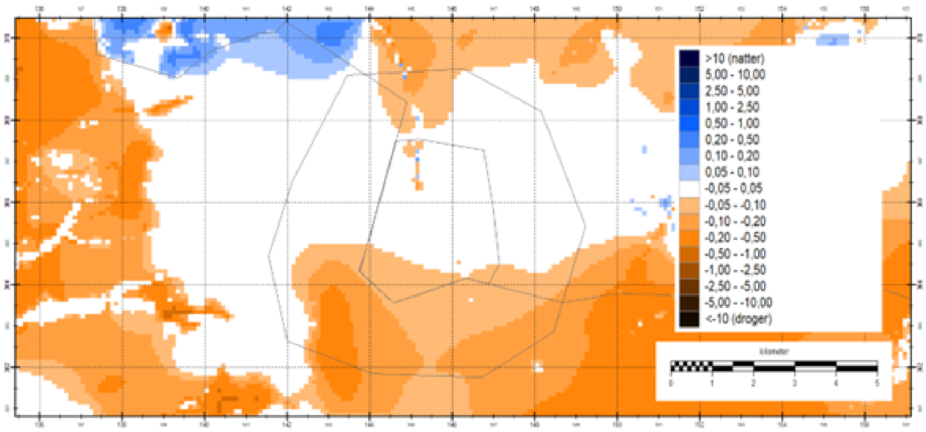


Figure B.40: Head difference for De Pielis and its surroundings for the "brook swamp" intervention for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

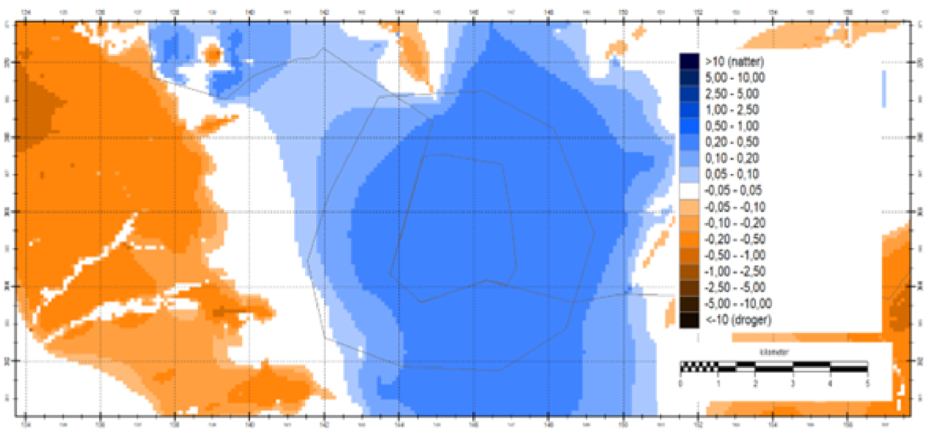


Figure B.41: Head difference for De Pielis and its surroundings for the "brook swamp" intervention for the 2085WHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

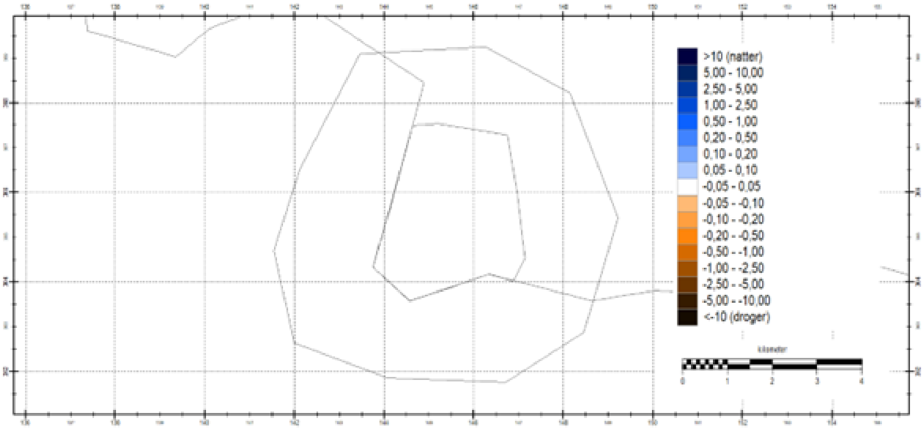


Figure B.42: Head difference for De Pielis and its surroundings for the "meandering" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

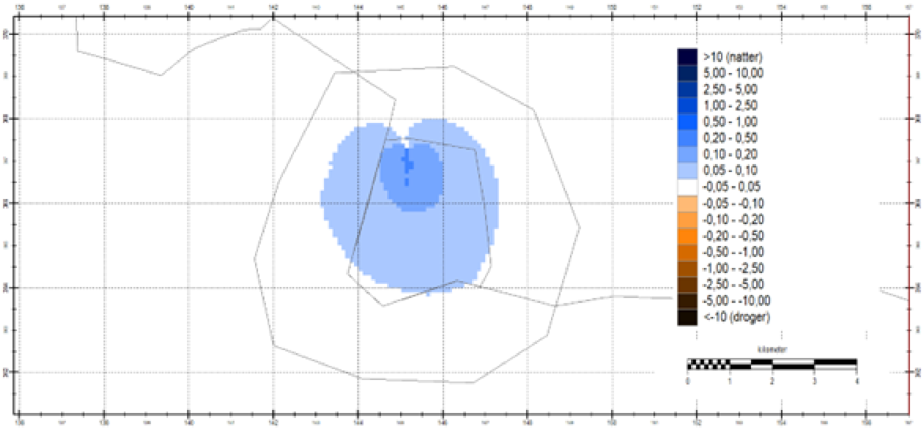


Figure B.43: Head difference for De Pielis and its surroundings for the "meandering" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

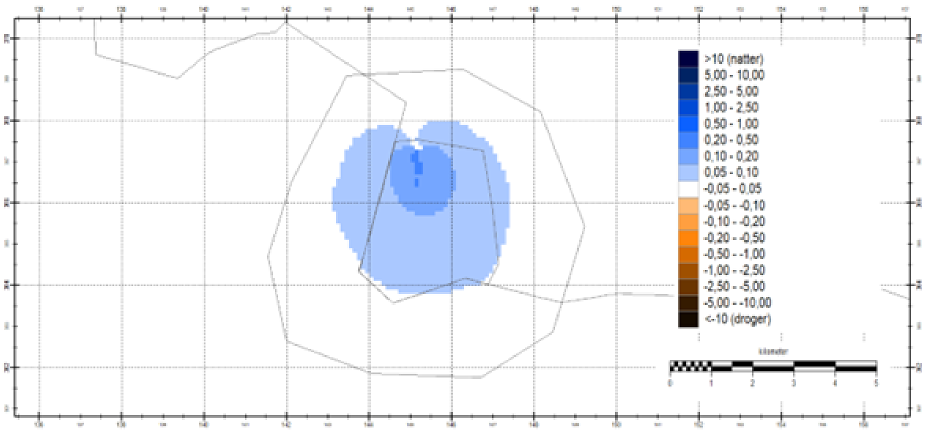


Figure B.44: Head difference for De Pielis and its surroundings for the "meandering" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

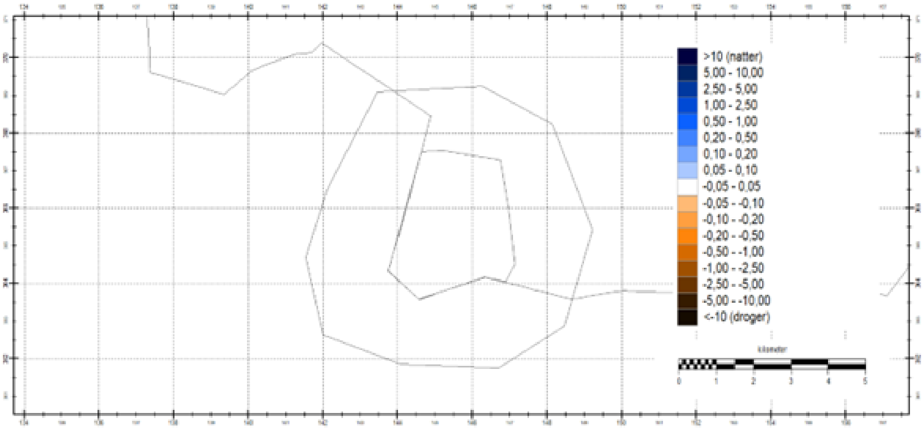


Figure B.45: Head difference for De Pielis and its surroundings for the "meandering" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

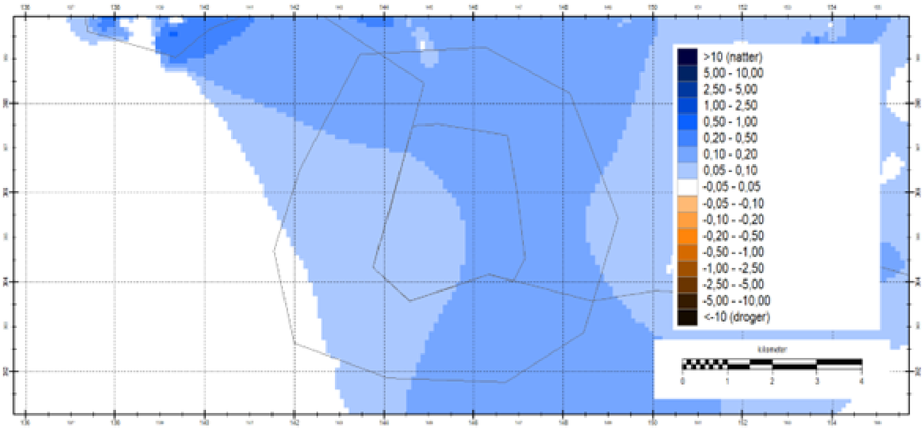


Figure B.46: Head difference for De Pielis and its surroundings for the "closed ditches" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

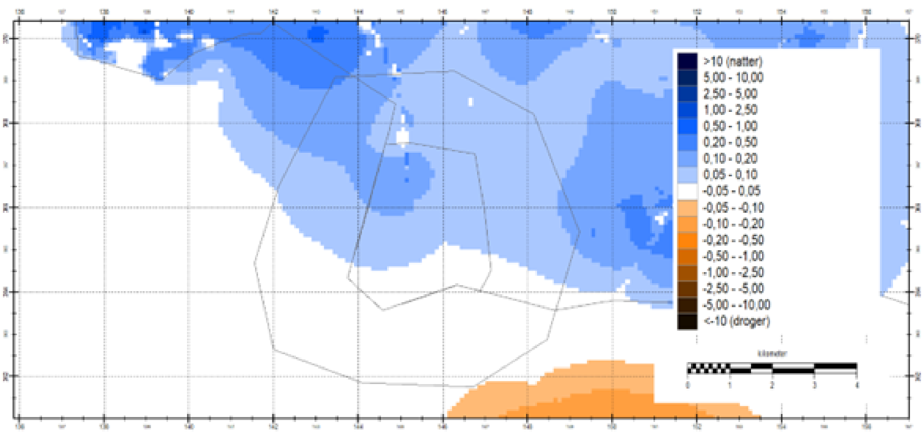


Figure B.47: Head difference for De Pielis and its surroundings for the "closed ditches" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

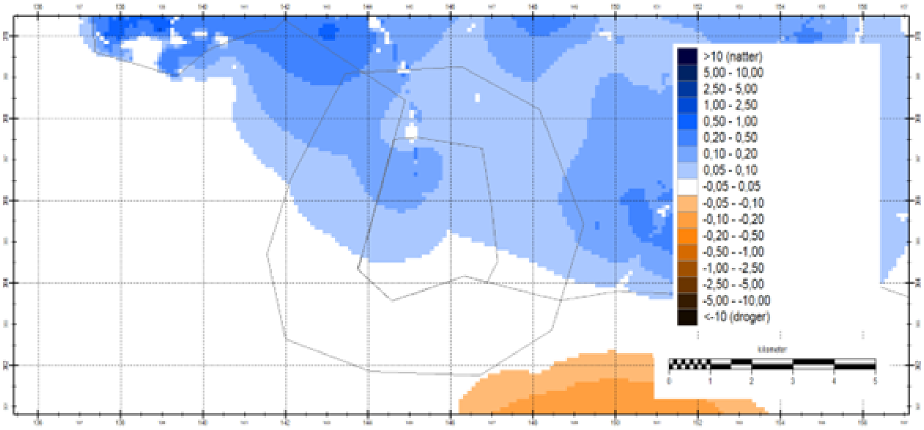


Figure B.48: Head difference for De Pielis and its surroundings for the "closed ditches" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

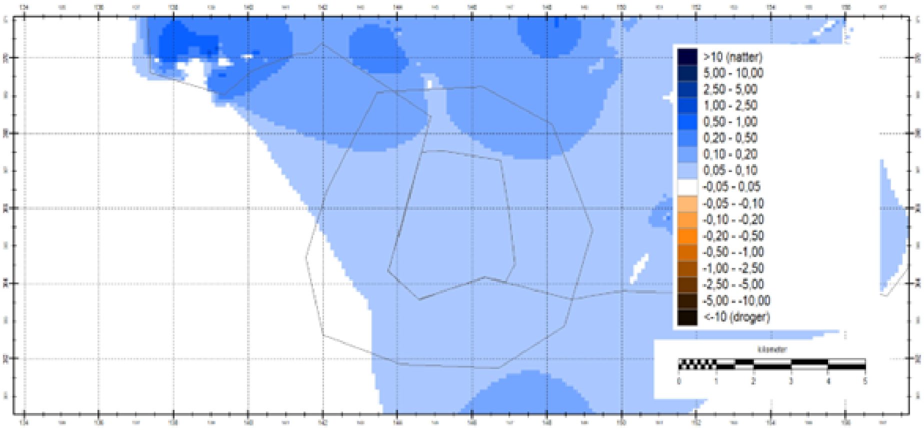


Figure B.49: Head difference for De Pielis and its surroundings for the "closed ditches" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

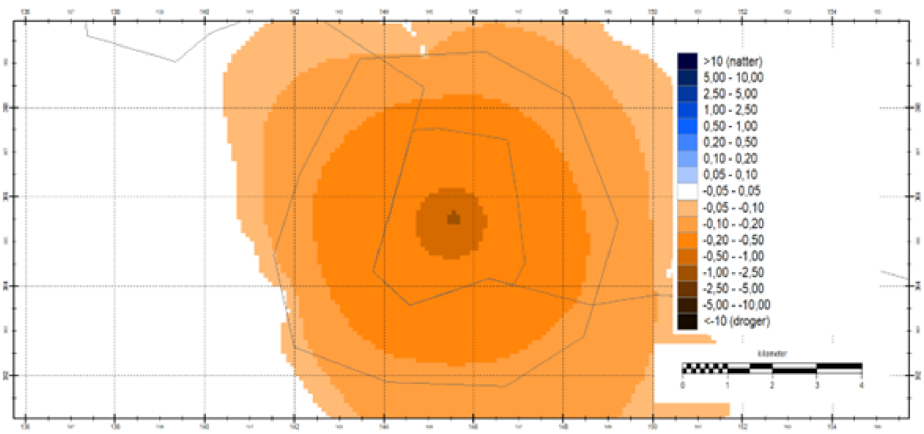


Figure B.50: Head difference for De Pielis and its surroundings for the "agricultural abstraction" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

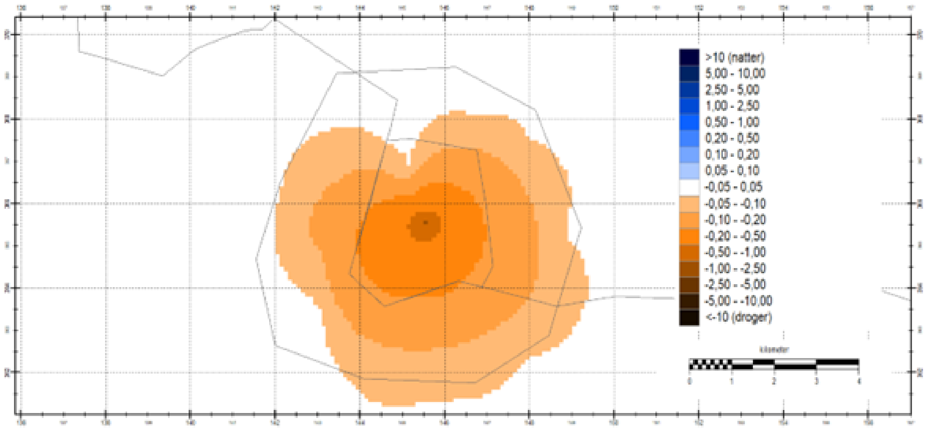


Figure B.51: Head difference for De Pielis and its surroundings for the "agricultural abstraction" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

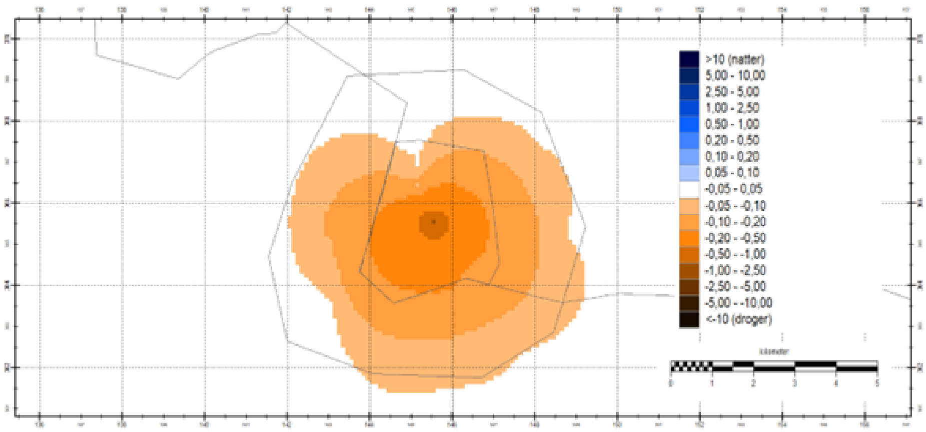


Figure B.52: Head difference for De Pielis and its surroundings for the "agricultural abstraction" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

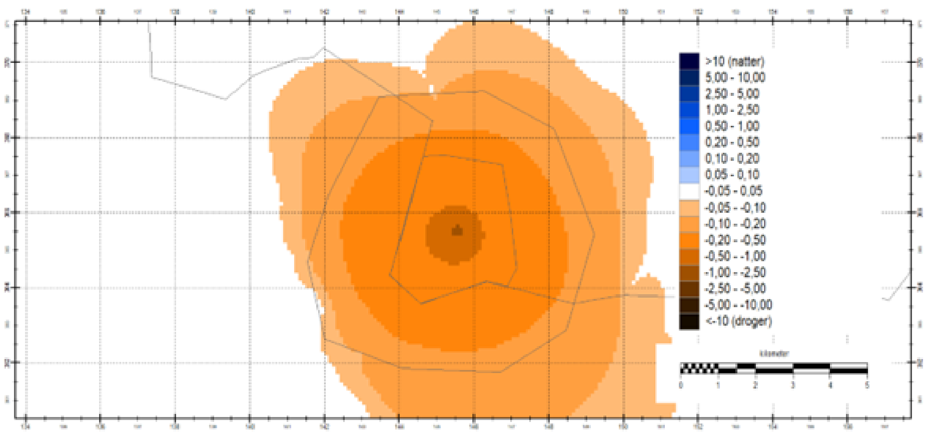


Figure B.53: Head difference for De Pielis and its surroundings for the "agricultural abstraction" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

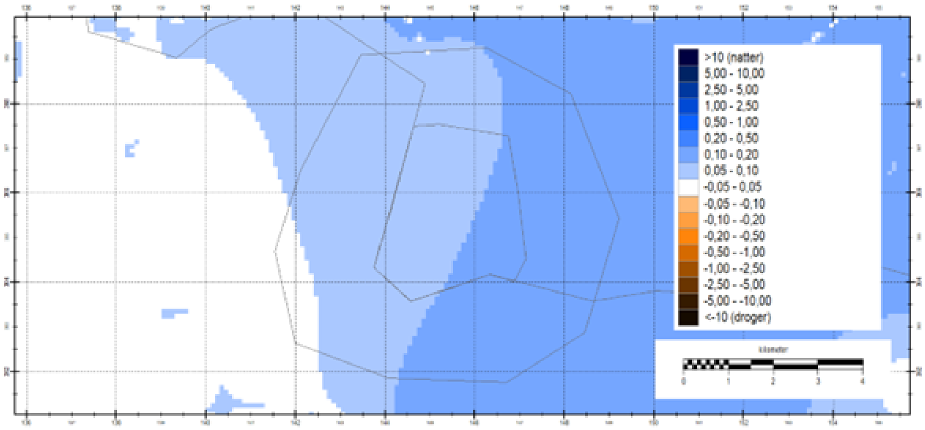


Figure B.54: Head difference for De Pielis and its surroundings for the "less mowing" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

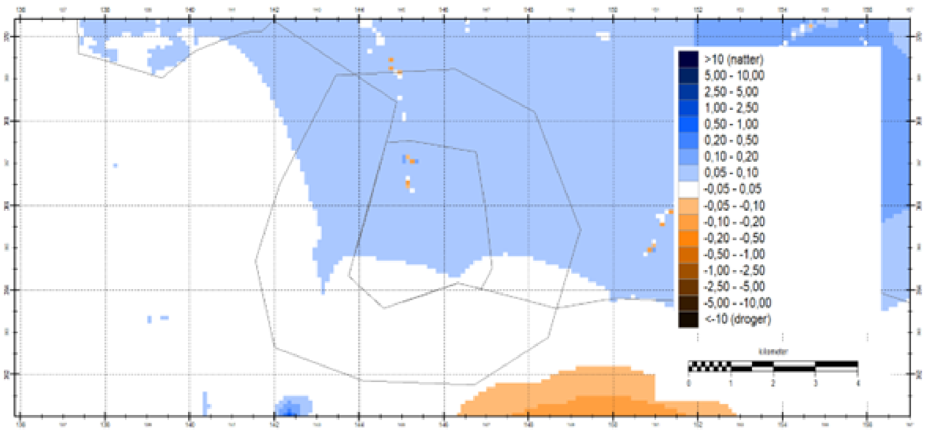


Figure B.55: Head difference for De Pielis and its surroundings for the "less mowing" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

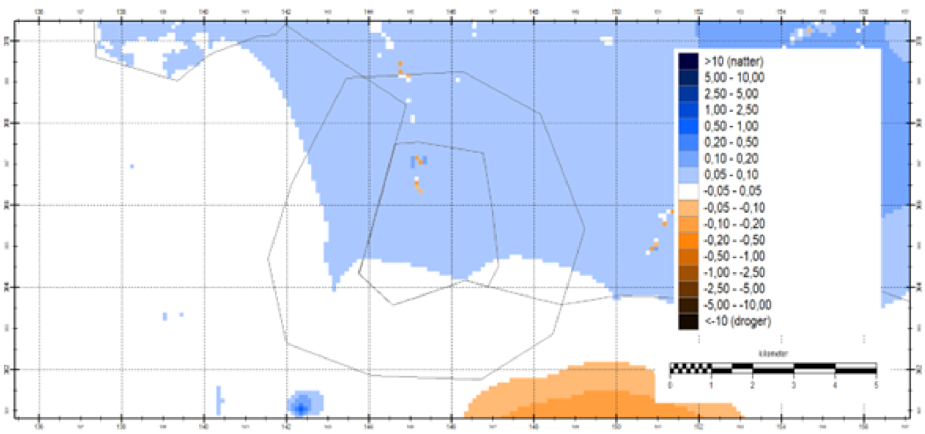


Figure B.56: Head difference for De Pielis and its surroundings for the "less mowing" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

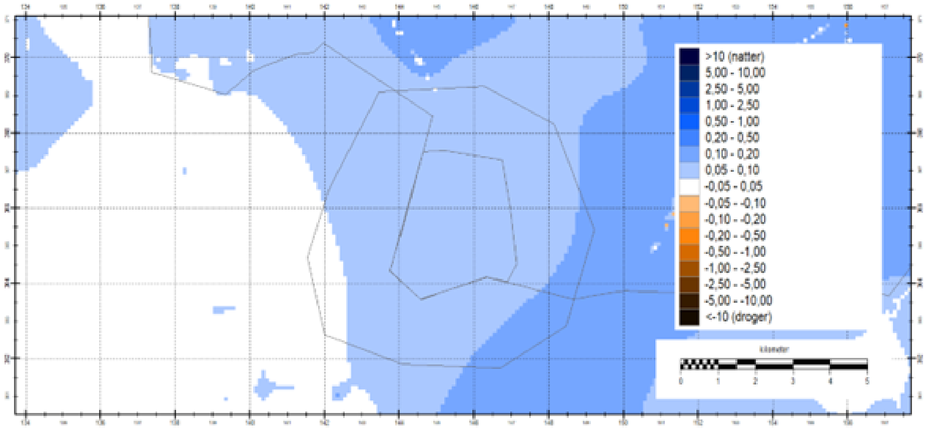


Figure B.57: Head difference for De Pielis and its surroundings for the "less mowing" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

B.1.3. Climate scenarios with combined interventions

Landschotse Heide

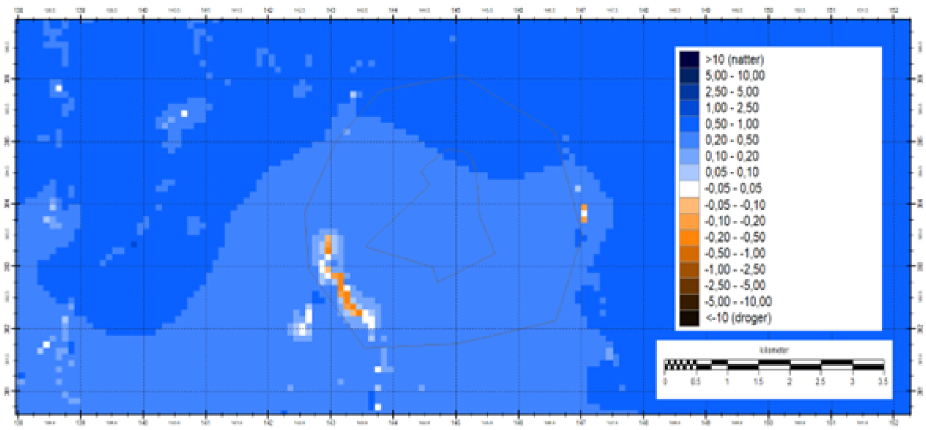


Figure B.58: Head difference for the Landschotse Heide and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

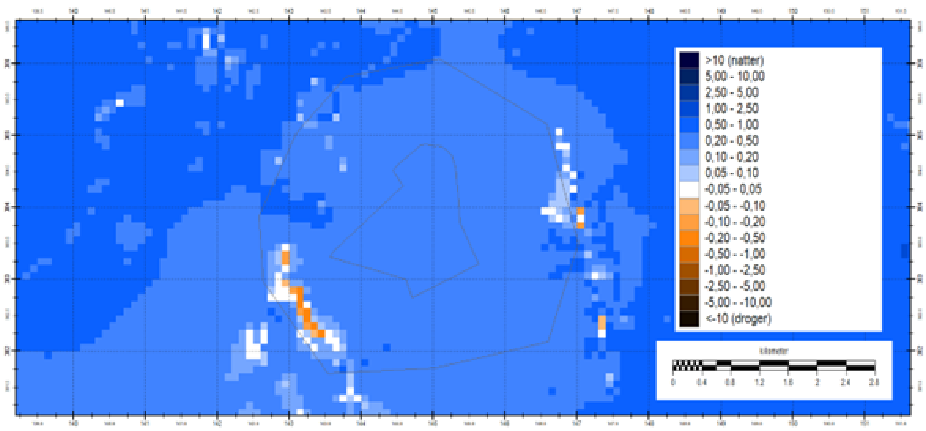


Figure B.59: Head difference for the Landschotse Heide and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

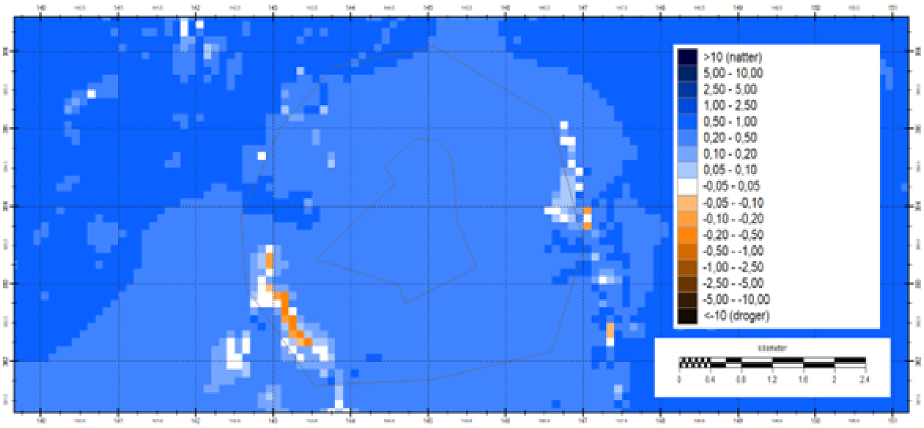


Figure B.60: Head difference for the Landschotse Heide and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

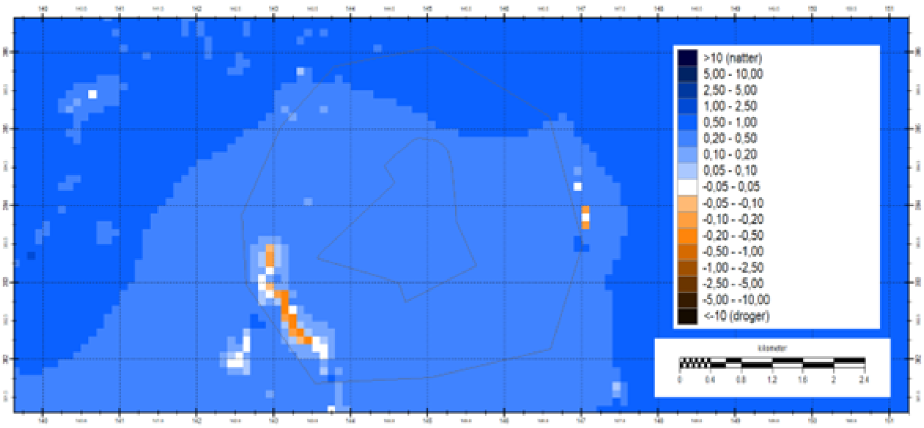


Figure B.61: Head difference for the Landschotse Heide and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

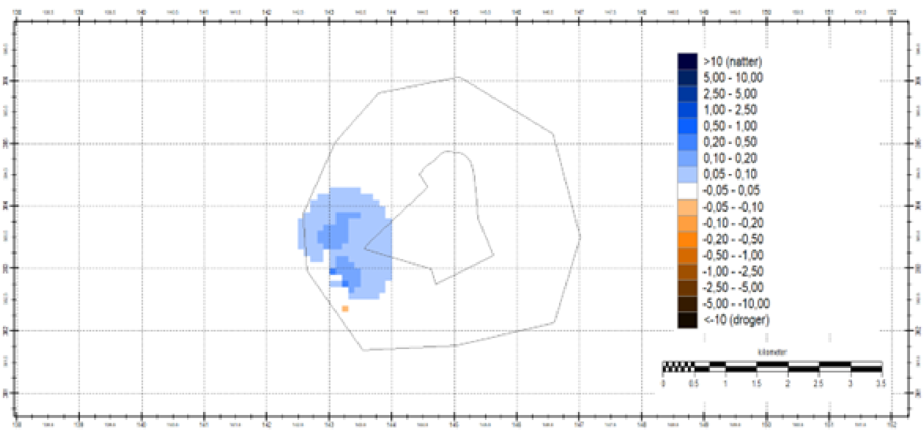


Figure B.62: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" intervention for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

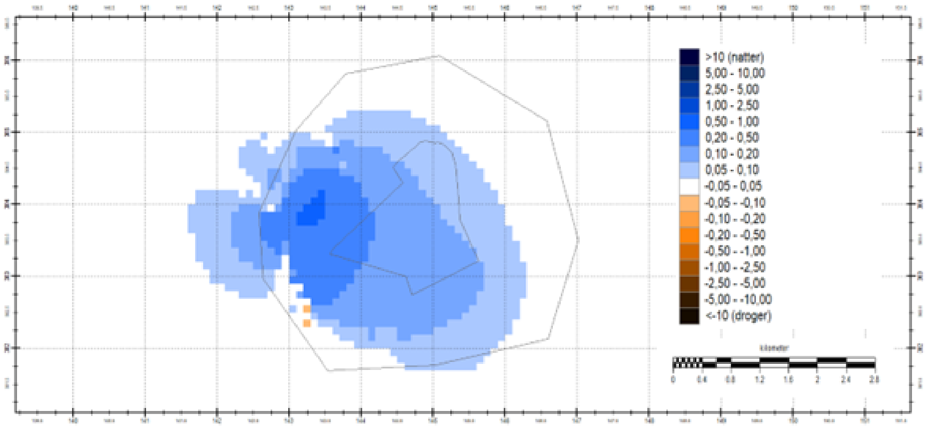


Figure B.63: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" intervention for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

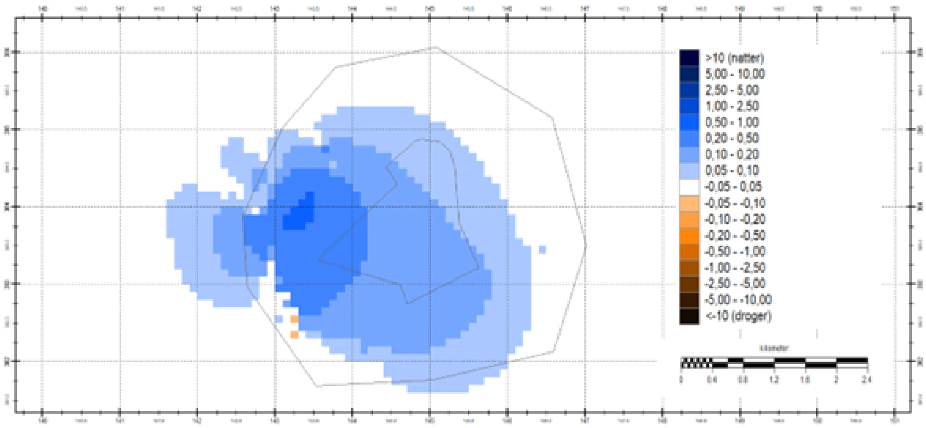


Figure B.64: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" intervention for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

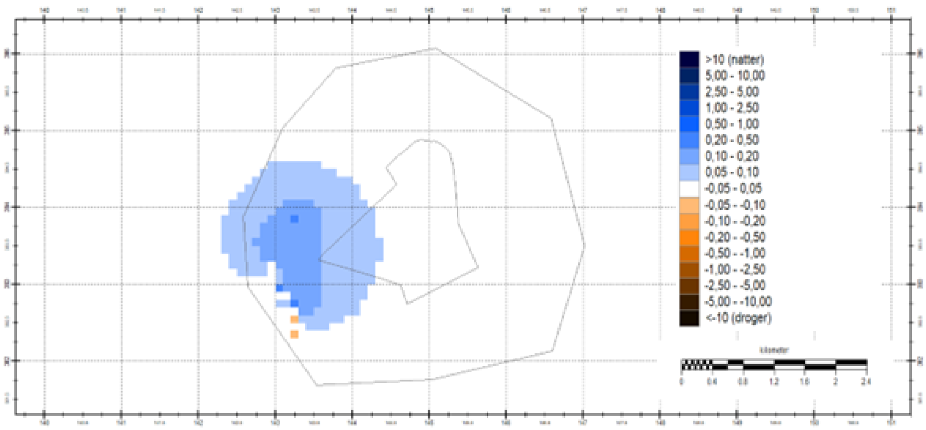


Figure B.65: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" intervention for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

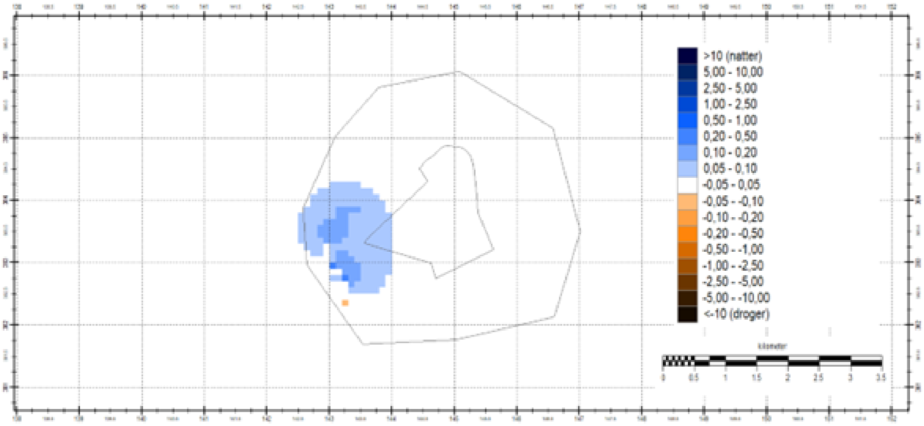


Figure B.66: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" and "effluent infiltration" interventions combined for the 2050GHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

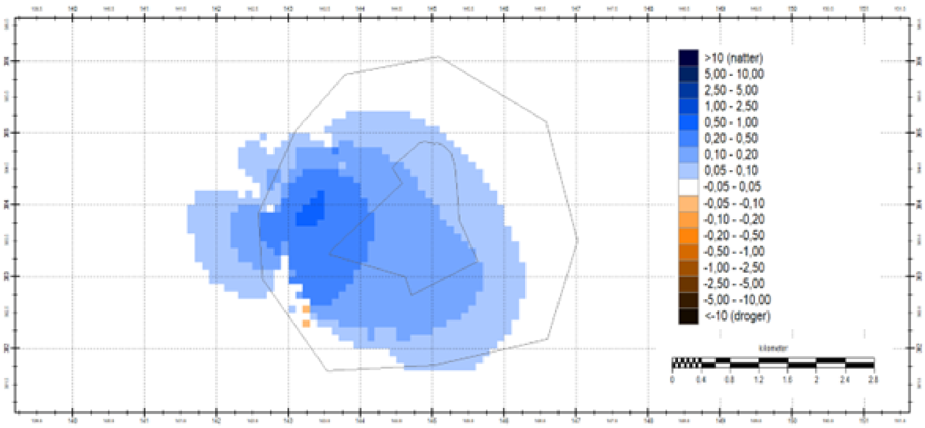


Figure B.67: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" and "effluent infiltration" interventions combined for the 2050WLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

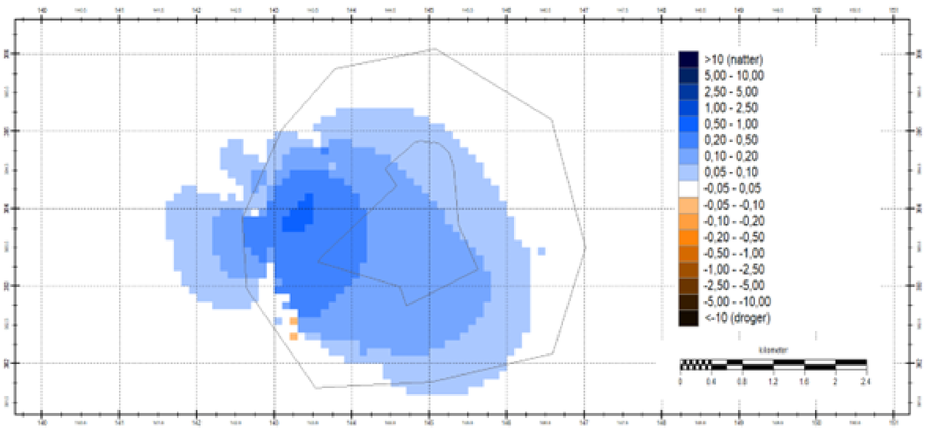


Figure B.68: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" and "effluent infiltration" interventions combined for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

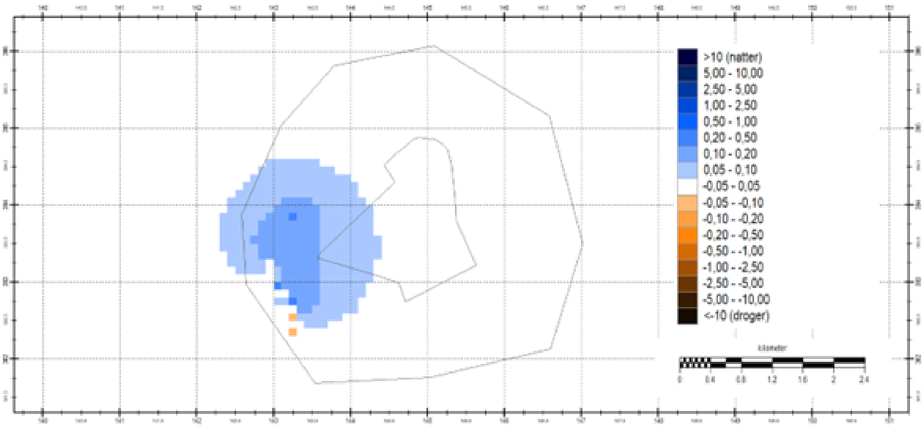


Figure B.69: Head difference for the Landschotse Heide and its surroundings for the "climate buffer" and "effluent infiltration" interventions combined for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

De Pielis

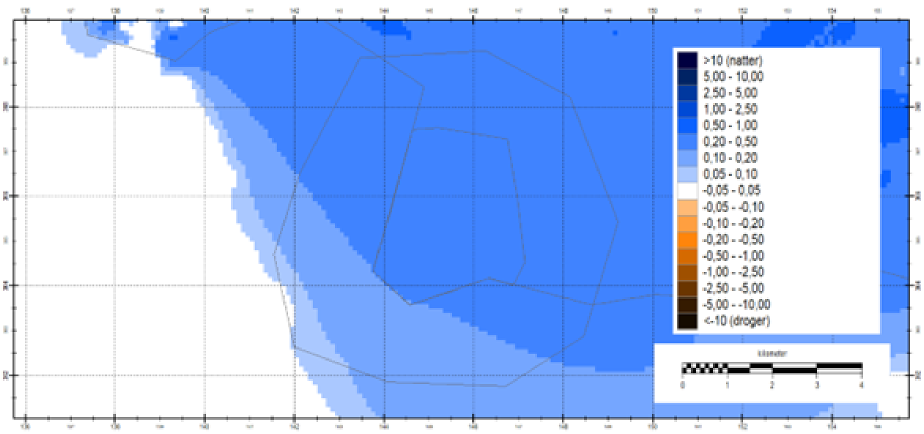


Figure B.70: Head difference for De Pieis and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

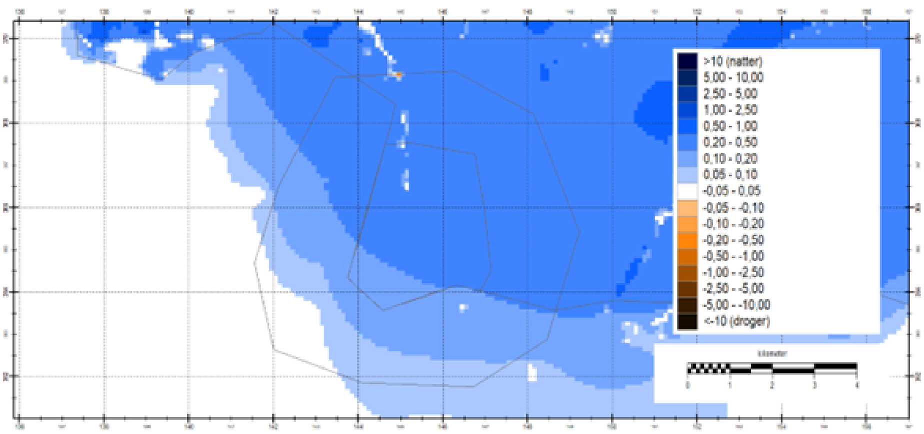


Figure B.71: Head difference for De Pielis and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

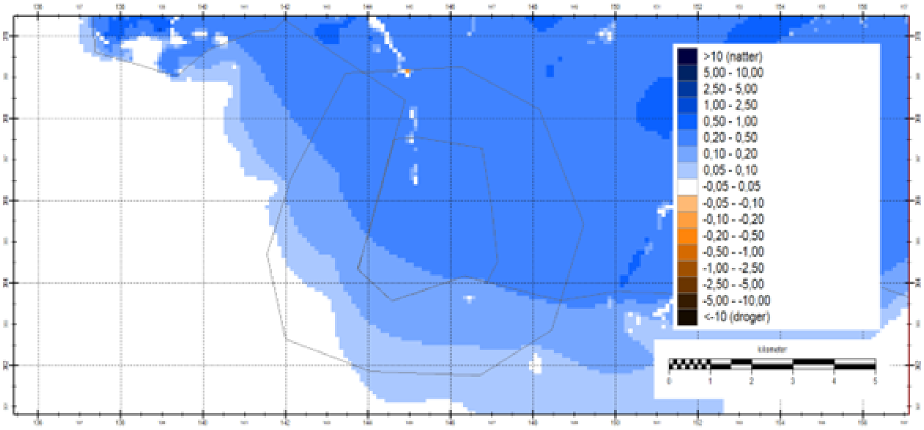


Figure B.72: Head difference for De Pielis and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

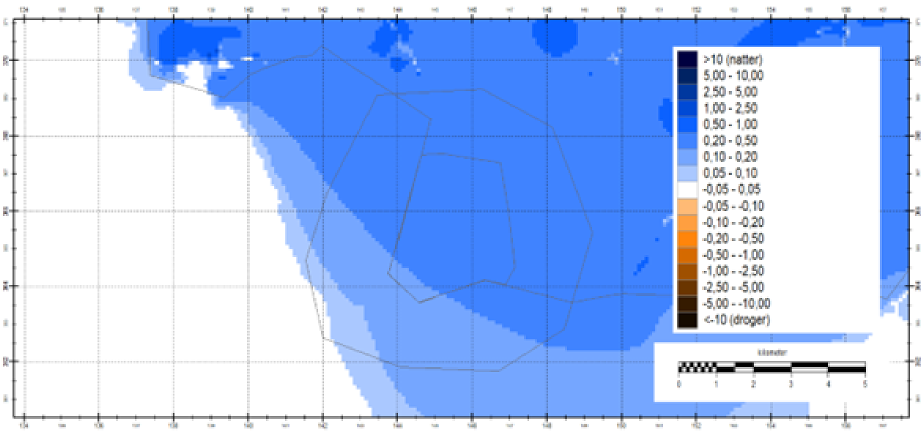


Figure B.73: Head difference for De Pielis and its surroundings for the "higher water level" and "closed ditches" interventions combined for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

B.1.4. Climate scenarios with abstraction scenarios

Landschotse Heide

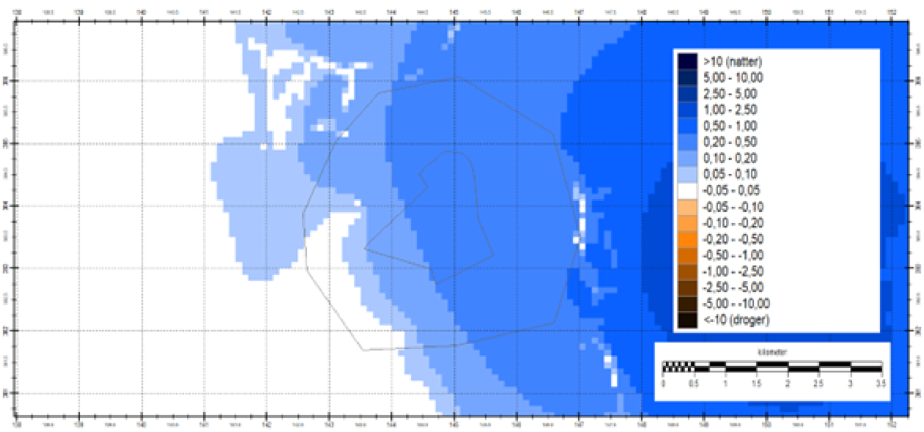


Figure B.74: Head difference for the Landschotse Heide and its surroundings for the no abstraction scenario for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

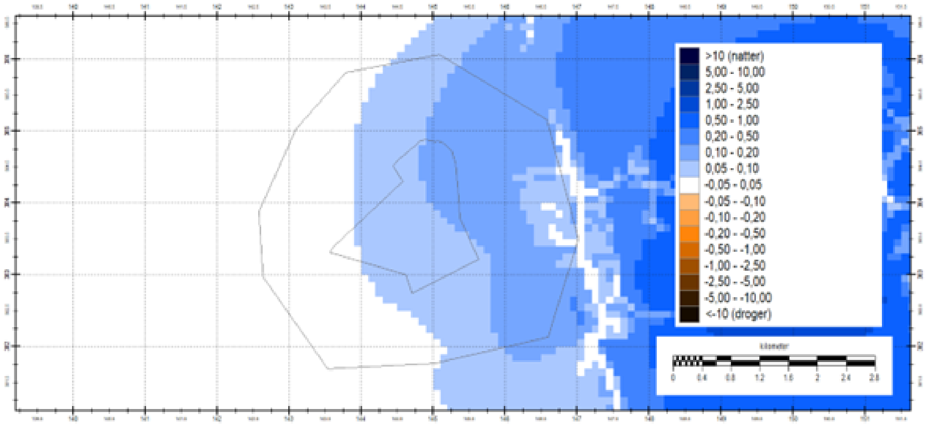


Figure B.75: Head difference for the Landschotse Heide and its surroundings for the no abstraction scenario for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

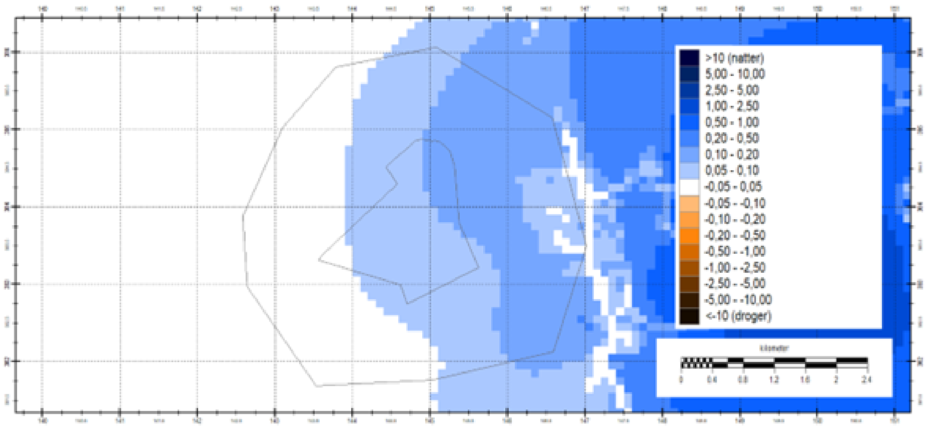


Figure B.76: Head difference for the Landschotse Heide and its surroundings for the no abstraction scenario for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

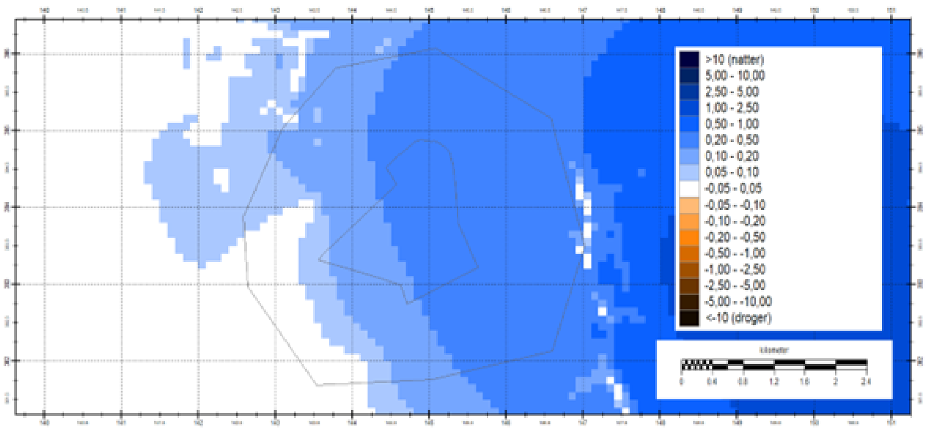


Figure B.77: Head difference for the Landschotse Heide and its surroundings for the no abstraction scenario for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

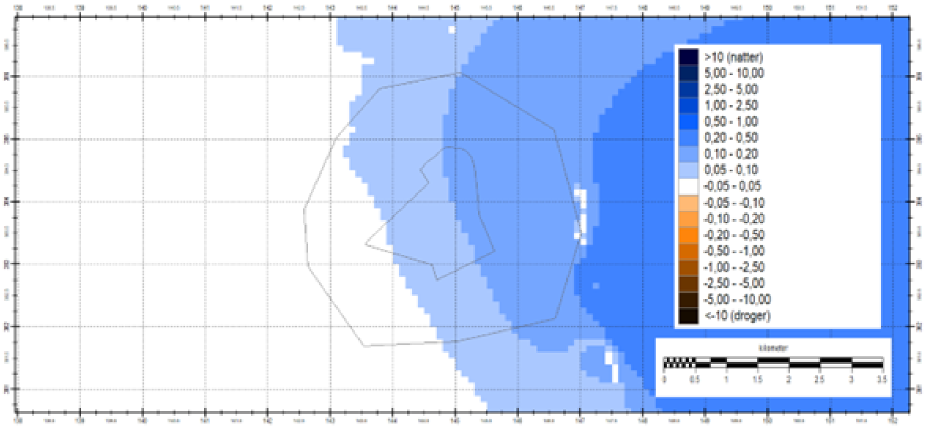


Figure B.78: Head difference for the Landschotse Heide and its surroundings for the 30% less abstraction scenario for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

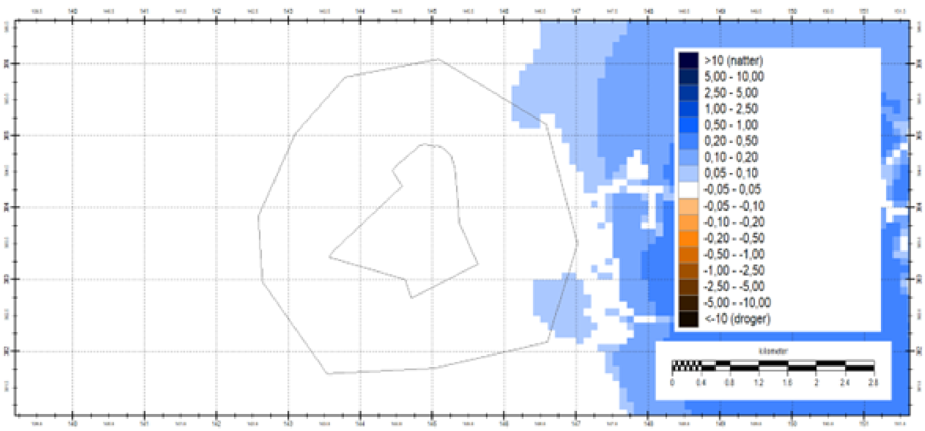


Figure B.79: Head difference for the Landschotse Heide and its surroundings for the 30% less abstraction scenario for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

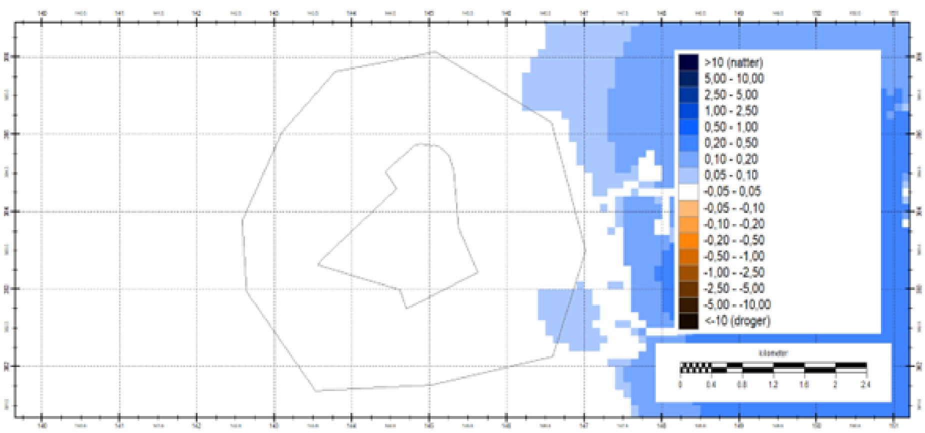


Figure B.80: Head difference for the Landschotse Heide and its surroundings for the 30% less abstraction scenario for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

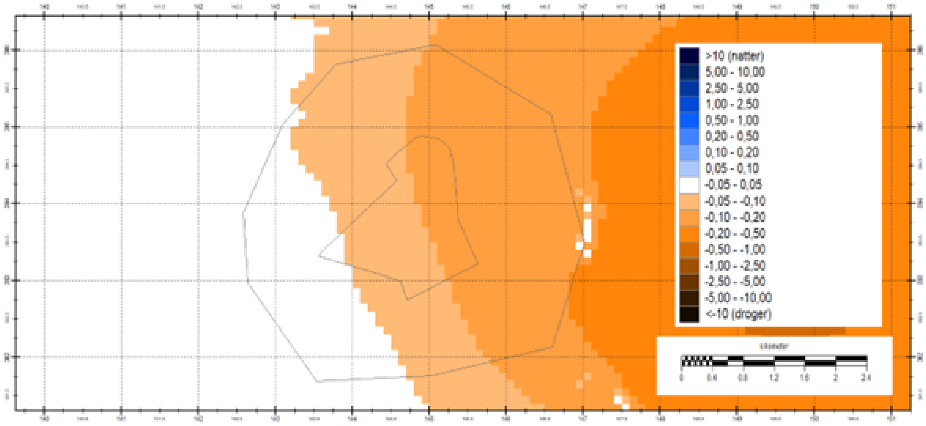


Figure B.81: Head difference for the Landschotse Heide and its surroundings for the 30% less abstraction scenario for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

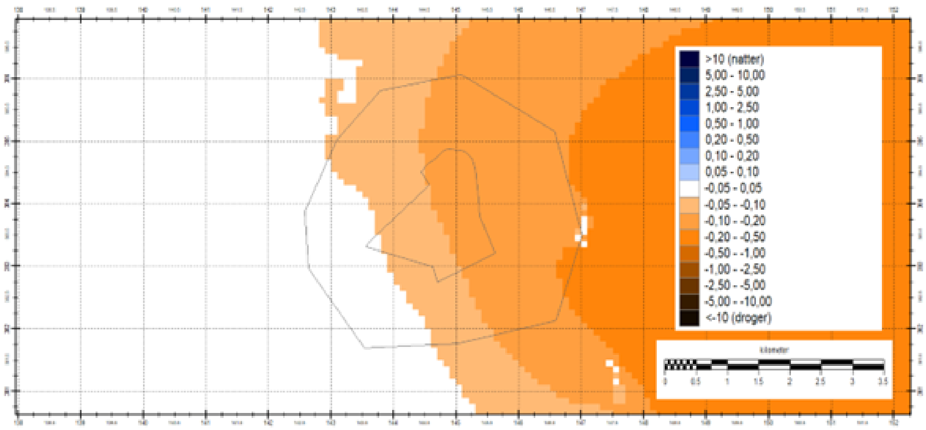


Figure B.82: Head difference for the Landschotse Heide and its surroundings for the 30% more abstraction scenario for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

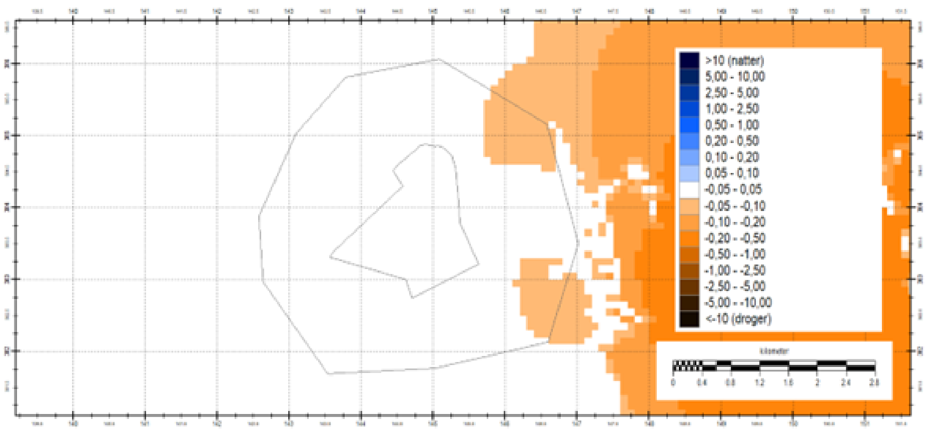


Figure B.83: Head difference for the Landschotse Heide and its surroundings for the 30% more abstraction scenario for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

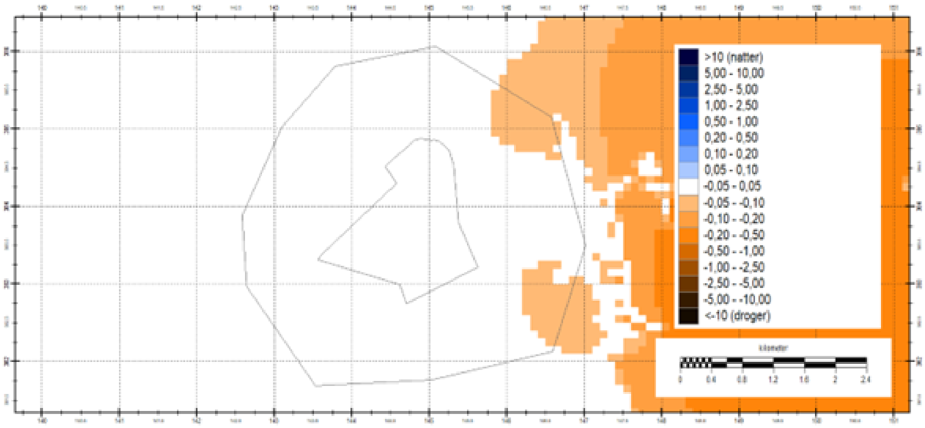


Figure B.84: Head difference for the Landschotse Heide and its surroundings for the 30% more abstraction scenario for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

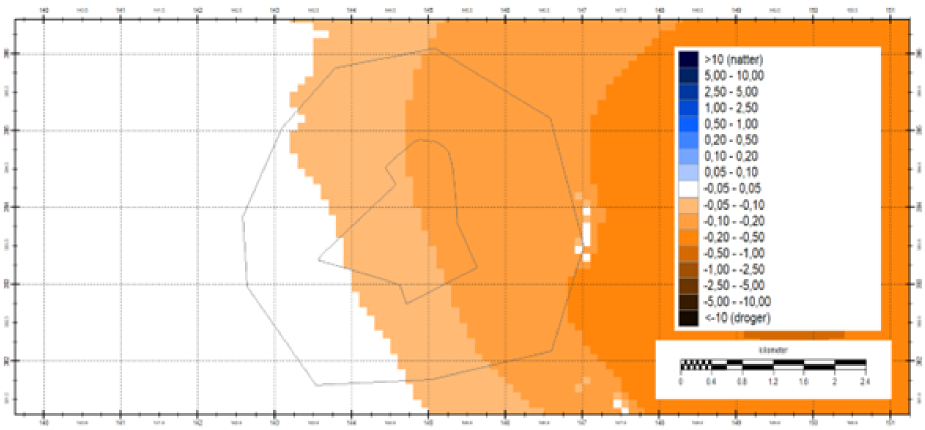


Figure B.85: Head difference for the Landschotse Heide and its surroundings for the 30% more abstraction scenario for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

De Pielis

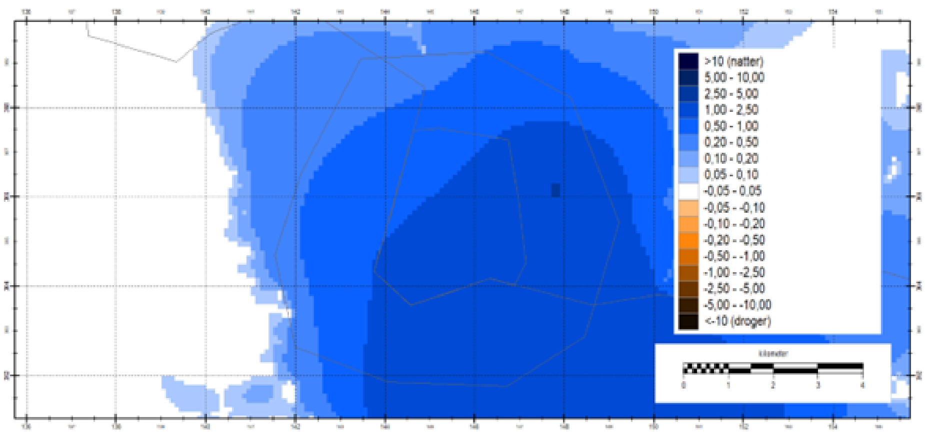


Figure B.86: Head difference for De Pielis and its surroundings for the no abstraction scenario for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

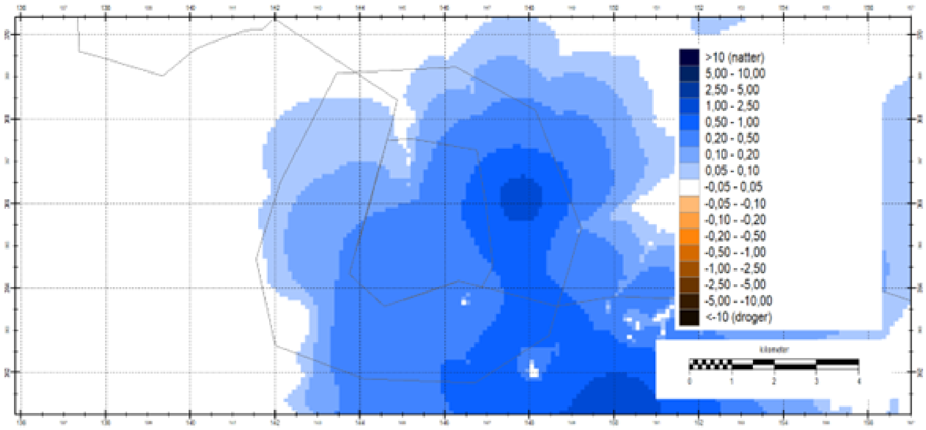


Figure B.87: Head difference for De Pielis and its surroundings for the no abstraction scenario for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

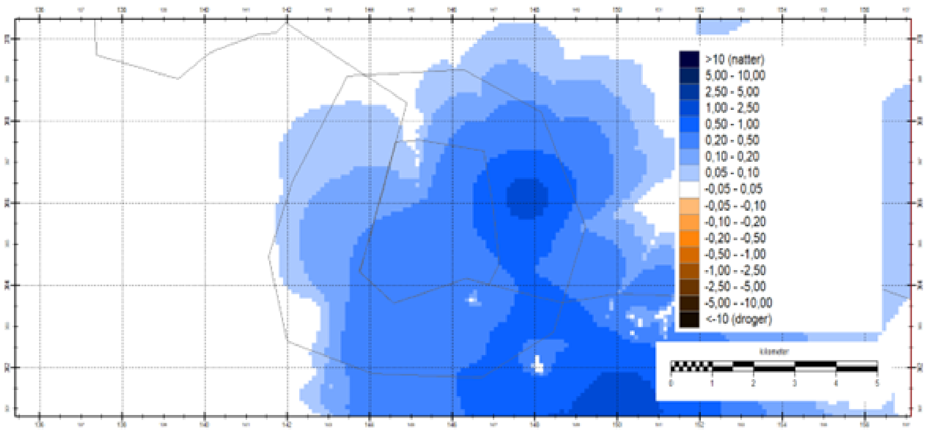


Figure B.88: Head difference for De Pielis and its surroundings for the no abstraction scenario for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

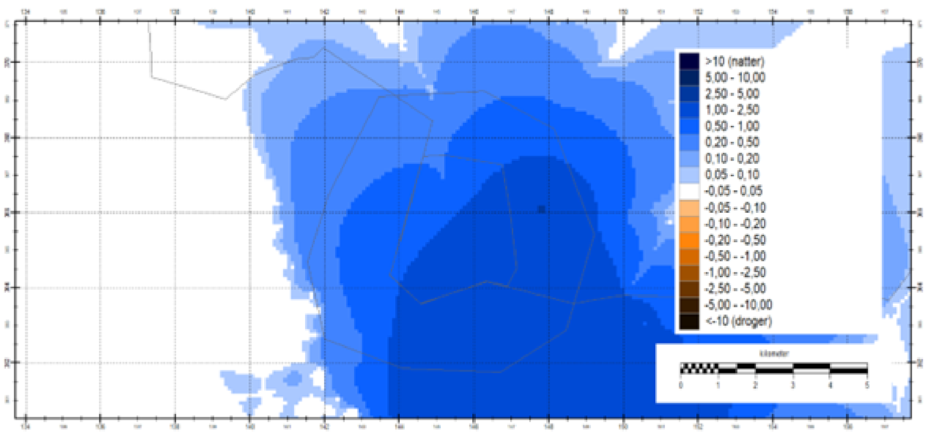


Figure B.89: Head difference for De Pielis and its surroundings for the no abstraction scenario for the 2085WHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

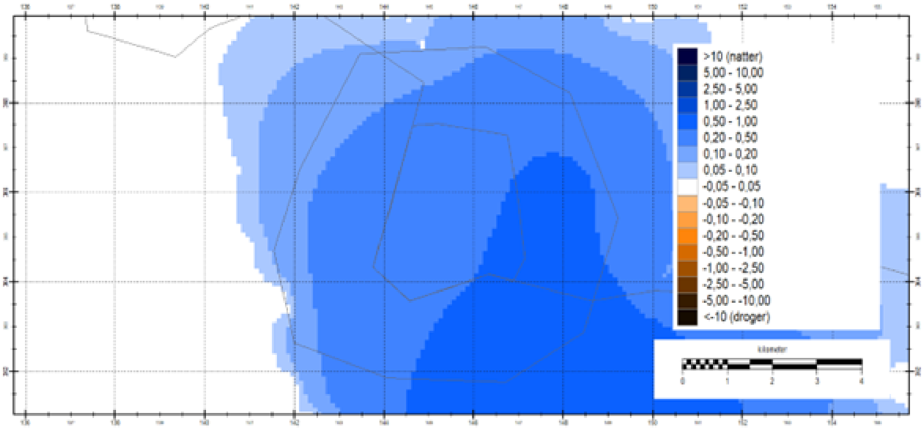


Figure B.90: Head difference for De Pielis and its surroundings for the 30% less abstraction scenario for the 2050GHmin scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

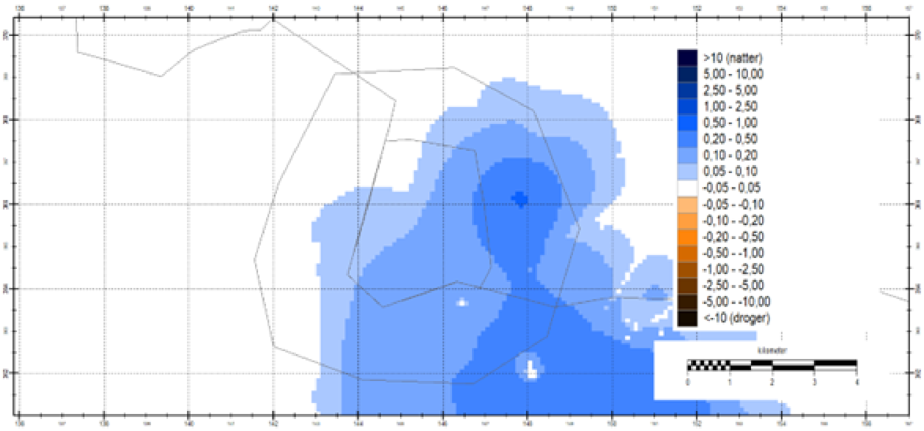


Figure B.91: Head difference for De Pielis and its surroundings for the 30% less abstraction scenario for the 2050WLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

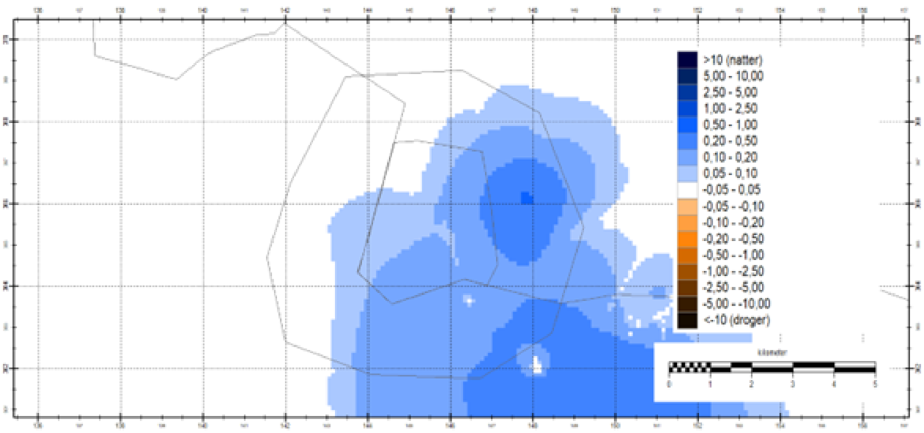


Figure B.92: Head difference for De Pielis and its surroundings for the 30% less abstraction scenario for the 2085GLmax scenario (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

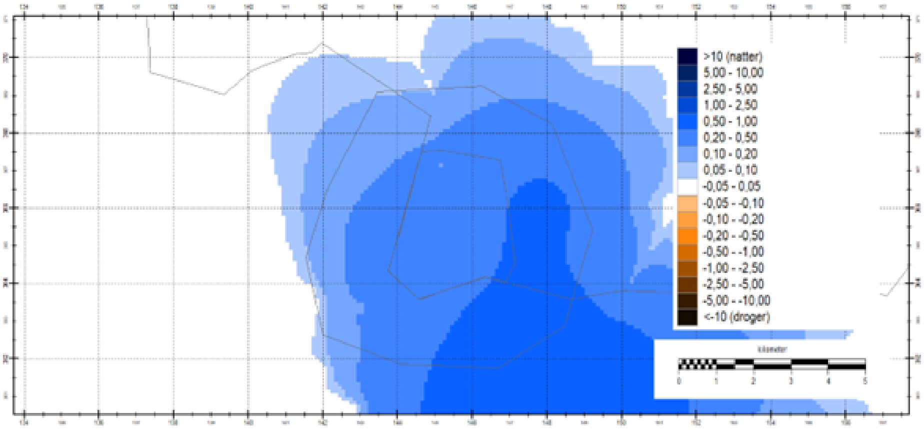


Figure B.93: Head difference for De Pielis and its surroundings for the 30% less abstraction scenario for the 2085WHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

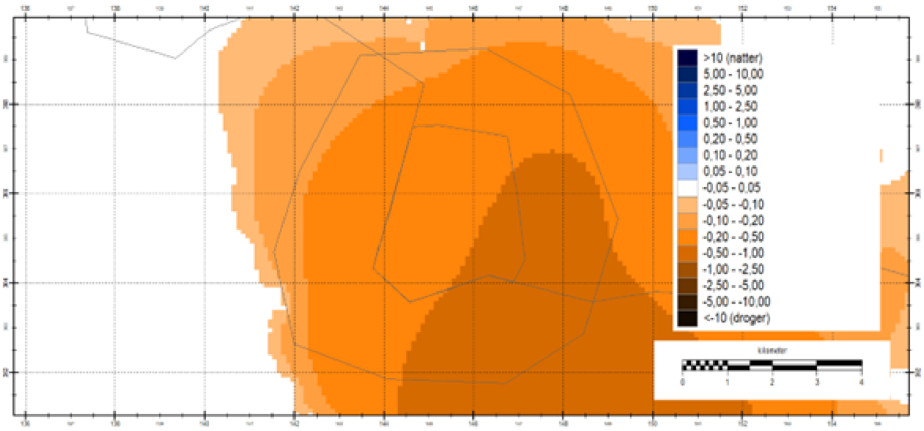


Figure B.94: Head difference for De Pielis and its surroundings for the 30% more abstraction scenario for the 2050GHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

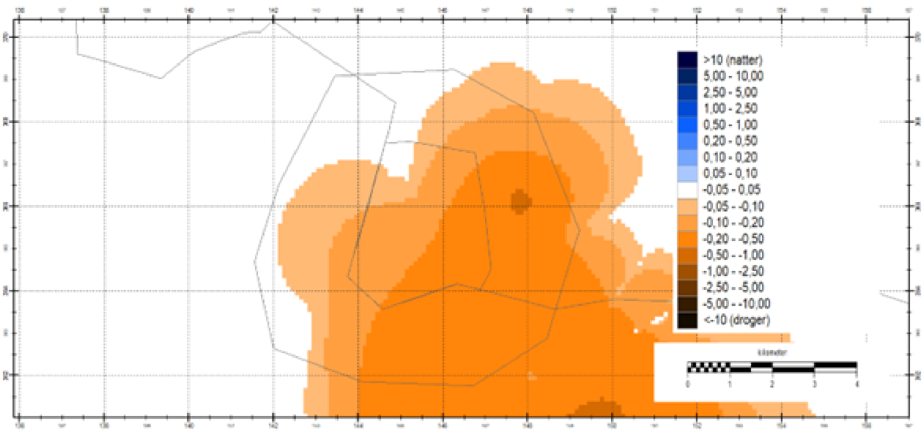


Figure B.95: Head difference for De Pielis and its surroundings for the 30% more abstraction scenario for the 2050WLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

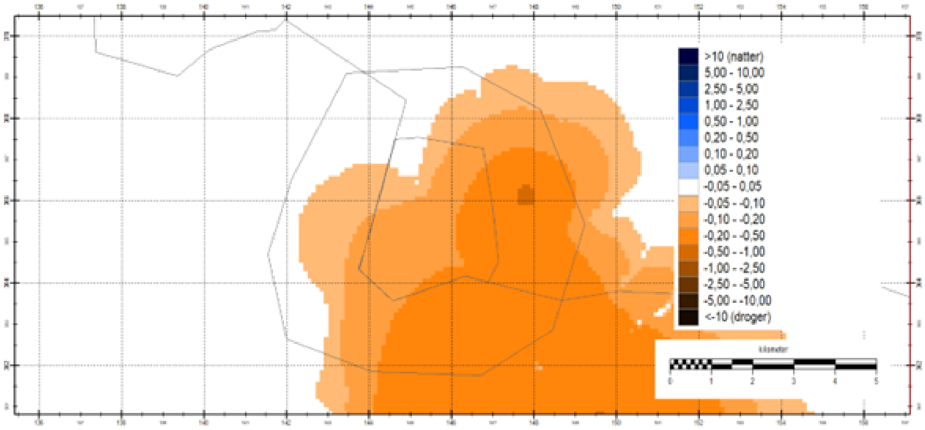


Figure B.96: Head difference for De Pielis and its surroundings for the 30% more abstraction scenario for the 2085GLmax scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

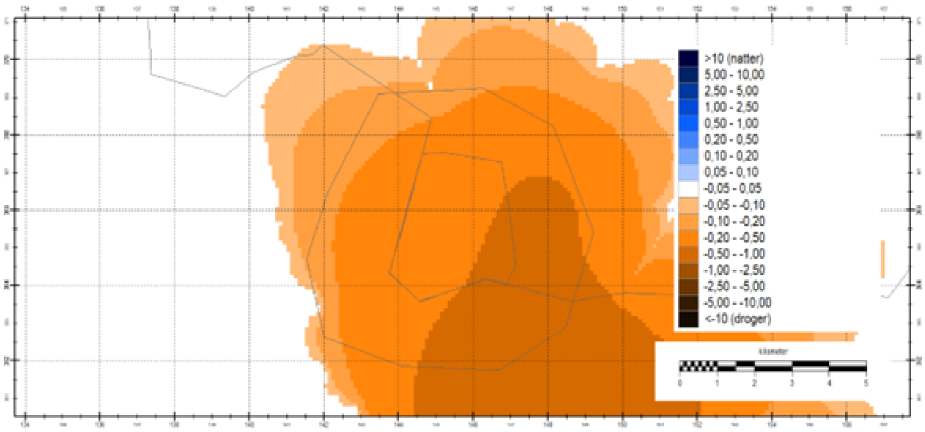


Figure B.97: Head difference for De Pielis and its surroundings for the 30% more abstraction scenario for the 2085WHmin scenario (legend in $meters$, 'natter'=wetter, 'droger'=dryer).

B.1.5. Non-stationary model

In this subsection the head differences for the Non-stationary model are shown for the year 2018.

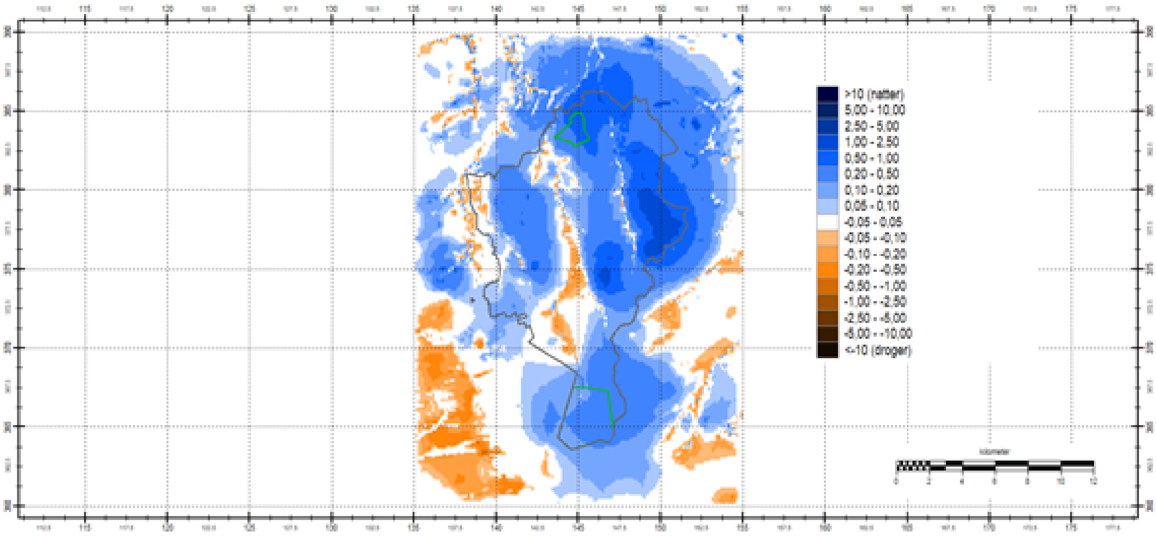


Figure B.98: Head difference for average high head of year 2018 for the Brook swamp intervention compared to the average high head of the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

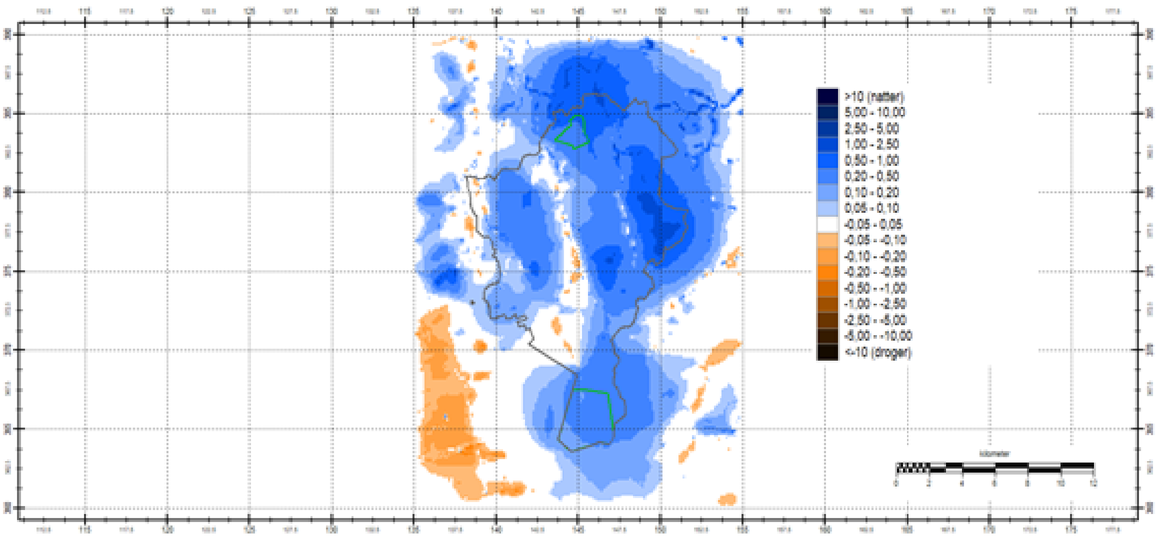


Figure B.99: Head difference for average low head of year 2018 for the Brook swamp intervention compared to the average low head of the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

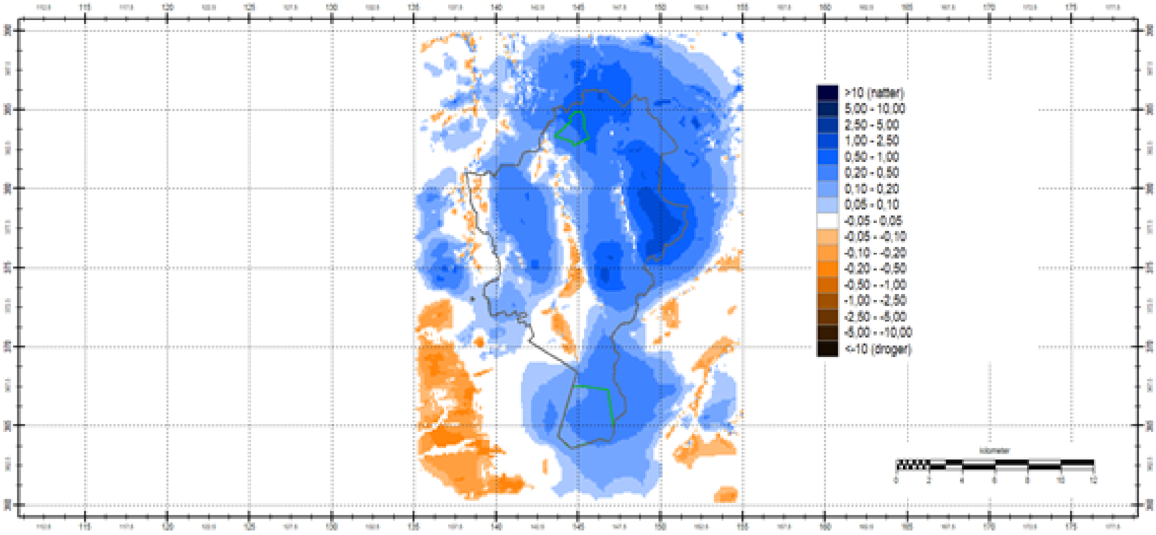


Figure B.100: Head difference for average spring head of year 2018 for the Brook swamp intervention compared to the average spring head of the BASE model (legend in *meters*, 'natter'=wetter, 'droger'=dryer).

B.2. Water balance

In this section the water balances which are not shown in the report are shown. For all tables the abbreviations mean the following: RCH: recharge, OLF: overland flow, DRN: drainage in B- and C-waterways, RIV: A-waterway discharge, FRF: flow through right front, FFF: flow through forward front and FLF: Flow through lower front.

B.2.1. Single interventions

Landschotse Heide

Table B.1: layer 1

	BASE model			Meandering			Effluent infiltration		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-1	-1	0	-1	-1
RIV	0	-25	-25	0	-25	-25	0	-25	-25
FRF	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0
FLF	15	-284	-269	15	-284	-269	15	-284	-268

Table B.2: layers 1-4

	BASE model			Meandering			Effluent infiltration		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	295	0	295	295	0	295	295	0	295
OLF	0	0	0	0	0	0	0	0	0
DRN	0	-8	-8	0	-8	-8	0	-8	-8
RIV	0	-104	-104	0	-103	-103	0	-106	-106
FRF	15	-28	-12	15	-28	-12	16	-29	-13
FFF	30	-89	-59	29	-89	-60	32	-89	-57
FLF	29	-140	-111	28	-140	-112	29	-140	-110

De Pielis

Table B.3: layer 1

	BASE model			Meandering			Effluent infiltration		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-1	-1	0	-1	-1
RIV	0	0	0	0	-1	-1	0	0	0
FRF	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0
FLF	1	-353	-352	1	-353	-352	1	-353	-352

Table B.4: layers 1-4

	BASE model			Meandering			Effluent infiltration		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	354	0	354	354	0	354	354	0	354
OLF	0	0	0	0	0	0	0	0	0
DRN	0	-7	-7	0	-10	-10	0	-7	-7
RIV	0	-28	-28	0	-22	-22	0	-28	-28
FRF	0	-8	-7	0	-8	-7	0	-8	-7
FFF	2	-17	-14	2	-17	-17	2	-17	-14
FLF	22	-319	-297	19	-319	-300	22	-319	-297

B.2.2. Climate scenarios combined with single interventions

Landschotse Heide
First aquifer layer

Table B.5: 2050GHmin layer 1

	2050GHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-2	-2	0	0	0	0	-1	-1
RIV	0	-18	-18	0	-26	-26	0	-30	-30	0	-18	-18
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	11	-232	-220	18	-229	-211	19	-229	-211	11	-232	-220

Table B.6: 2050GHmin layer 1

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	-1	-1	0	-1	-1
RIV	0	-21	-21	0	-16	-16	0	-18	-18	0	-19	-19
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	13	-232	-218	10	-232	-222	12	-232	-220	13	-231	-219

Table B.7: 2050WLmax layer 1 LH

	2050WLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-5	-5	0	-34	-34	0	-6	-6	0	-5	-5
RIV	0	-35	-35	0	-47	-47	0	-53	-53	0	-35	-35
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	20	-344	-323	55	-337	-282	37	-341	-303	20	-344	-323

Table B.8: 2050WLmax layer 1 LH

	Closed ditches			Agricultural abstraction			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	-9	-9	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-3	-3	0	-5	-5	0	-11	-11
RIV	0	-40	-40	0	-32	-32	0	-35	-35	0	-37	-37
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	28	-343	-314	17	-345	-328	20	-343	-323	26	-342	-315

Table B.9: 2085GLmax layer 1

	2085GLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	ÌN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-5	-5	0	-35	-35	0	-6	-6	0	-5	-5
RIV	0	-35	-35	0	-35	-35	0	-54	-54	0	-36	-36
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	21	-347	-326	57	-341	-284	38	-345	-307	21	-347	-326

Table B.10: 2085GLmax layer 1

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	ÌN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	-10	-10	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-3	-3	0	-5	-5	0	-11	-11
RIV	0	-40	-40	0	-33	-33	0	-35	-35	0	-37	-37
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	29	-346	-317	18	-349	-331	21	-347	-326	27	-345	-318

Table B.11: 2085WHmin layer 1

	2085WHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-3	-3	0	0	0	0	-1	-1
RIV	0	-19	-19	0	-28	-28	0	-32	-32	0	-19	-19
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	12	-242	-229	20	-238	-218	20	-239	-218	12	-242	-229

Table B.12: 2085WHmin layer 1

	Closed ditches			Agricultural abstraction			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-1	-1	0	-1	-1	0	-1	-1
RIV	0	-21	-21	0	-18	-18	0	-19	-19	0	-21	-21
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	14	-241	-227	11	-242	-231	12	-242	-229	13	-241	-228

First four aquifer layers combined

Table B.13: 2050GHmin layers 1-4

	2050GHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-3	-3	0	-3	-3	0	0	0	0	-3	-3
RIV	0	-60	-60	0	-84	-84	55	-89	-34	0	-59	-59
FRF	10	-25	-15	17	-23	-6	9	-28	-19	10	-25	-25
FFF	31	-85	-55	33	-80	-47	29	-85	-56	30	-85	-55
FLF	19	-125	-106	20	-120	-100	16	-146	-131	19	-126	-107

Table B.14: 2050GHmin layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-2	-2	0	-3	-3	0	-3	-3
RIV	0	-71	-71	0	-49	-49	0	-62	-62	0	-59	-59
FRF	14	-25	-12	11	-21	-10	11	-26	-15	10	-25	-15
FFF	32	-85	-53	32	-81	-50	33	-86	-53	30	-85	-55
FLF	21	-124	-103	15	-145	-130	19	-126	-106	18	-125	-107

Table B.15: 2050WLmax layers 1-4

	2050WLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-17	-17	0	-38	-38	0	-8	-8	0	-17	-17
RIV	0	-154	-154	0	-161	-161	34	-184	-150	0	-151	-151
FRF	18	-32	-14	24	-26	-2	16	-29	-13	18	-32	-14
FFF	30	-92	-62	31	-84	-53	31	-93	-62	29	-92	-63
FLF	36	-152	-116	43	-151	-108	33	-163	-130	36	-154	-118

Table B.16: 2050WLmax layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	-9	-9	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-13	-13	0	-17	-17	0	-22	-22
RIV	0	-180	-180	0	-132	-132	0	-156	-156	0	-149	-149
FRF	24	-29	-5	18	-29	-11	18	-32	-14	17	-31	-14
FFF	32	-93	-61	30	-89	-58	32	-92	-60	30	-91	-62
FLF	41	-148	-107	31	-179	-148	37	-152	-115	36	-153	-116

Table B.17: 2085GLmax layers 1-4

	2085GLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	ÌN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-18	-18	0	-39	-39	0	-8	-8	0	-18	-18
RIV	0	-157	-157	0	-164	-164	33	-187	-154	0	-154	-154
FRF	18	-32	-14	24	-26	-2	16	-29	-13	18	-32	-14
FFF	30	-92	-62	31	-84	-53	31	-93	-62	29	-92	-63
FLF	37	-153	-116	43	-152	-109	33	-163	-130	37	-154	-118

Table B.18: 2085GLmax layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	ÌN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	-10	-10	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-13	-13	0	-18	-18	0	-23	-23
RIV	0	-184	-184	0	-135	-135	0	-159	-159	0	-152	-152
FRF	24	-29	-5	18	-29	-11	18	-33	-14	18	-31	-14
FFF	32	-93	-61	30	-89	-159	32	-92	-60	30	-92	-62
FLF	41	-148	-107	32	-180	-148	37	-152	-115	37	-153	-116

Table B.19: 2085WHmin layers 1-4

	2085WHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-4	-14	0	-5	-5	0	0	0	0	-4	-4
RIV	0	-68	-68	0	-91	-91	53	-96	-43	0	-67	-67
FRF	11	-26	-15	18	-23	-6	9	-28	-18	11	-26	-15
FFF	30	-86	-55	33	-80	-47	29	-86	-57	30	-86	-56
FLF	20	-128	-108	22	-122	-101	17	-149	-131	20	-129	-109

Table B.20: 2085WHmin layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-2	-2	0	-4	-4	0	-4	-4
RIV	0	-79	-79	0	-54	-54	0	-69	-69	0	-66	-66
FRF	15	-26	-12	11	-21	-10	11	-27	-15	11	-26	-15
FFF	32	-85	-54	32	-82	-50	33	-86	-53	30	-86	-55
FLF	23	-127	-104	16	-149	-133	21	-129	-108	20	-129	-109

De Pielis

First aquifer layer

Table B.21: 2050GHmin layer 1

	2050GHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-239	-239	0	-239	-239	0	-239	-239	0	-239	-239

Table B.22: 2050GHmin layer 1

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-239	-239	0	-239	-239	0	-239	-239	0	-239	-239

Table B.23: 2050WLmax layer 1

	2050WLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-6	-6	0	-17	-17	0	-3	-3	0	-6	-6
RIV	0	0	0	0	-3	-3	0	-1	-1	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-360	-357	15	-357	-342	2	-361	-359	3	-359	-356

Table B.24: 2050WLmax layer 1

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	-6	-6	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-5	-5	0	-6	-6	0	-7	-7
RIV	0	0	0	0	0	0	0	0	0	0	-1	-1
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	4	-360	-356	3	-360	-357	3	-360	-357	4	-359	-354

Table B.25: 2085GLmax layer 1

	2085GLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-6	-6	0	-19	-19	0	-3	-3	0	-6	-6
RIV	0	0	0	0	-3	-3	0	-1	-1	0	-1	-1
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-363	-360	16	-361	-345	2	-365	-363	4	-363	-359

Table B.26: 2085GLmax layer 1

	Closed Ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	-6	-6	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-6	-6	0	-6	-6	0	-8	-8
RIV	0	0	0	0	0	0	0	0	0	0	-1	-1
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	4	-364	-360	3	-364	-361	3	-364	-360	5	-362	-358

Table B.27: 2085WHmin layer 1

	2085WHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-249	-249	0	-249	-249	0	-249	-249	0	-249	-249

Table B.28: 2085WHmin layer 1

	Closed Ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-249	-249	0	-249	-249	0	-249	-249	0	-249	-249

Top four aquifer layers combined

Table B.29: 2050GHmin layers 1-4

	2050GHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	-1	-1	0	0	0	27	-6	21	0	-1	-1
FRF	0	-4	-4	0	-4	-4	0	-5	-5	0	-4	-4
FFF	2	-12	-10	2	-11	-9	2	-14	-11	2	-12	-10
FLF	1	-226	-225	0	-226	-226	4	-248	-244	1	-226	-225

Table B.30: 2050GHmin layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	-2	-2	0	0	0	0	-1	-1	0	-1	-1
FRF	0	-4	-4	0	-3	-3	0	-4	-4	0	-4	-4
FFF	2	-12	-9	2	-11	-8	2	-12	-10	2	-12	-9
FLF	1	-226	-225	1	-228	-227	1	-226	-225	1	-226	-225

Table B.31: 2050GLmax layers 1-4

	2050WLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-14	-14	0	-20	-20	0	-3	-3	0	-18	-18
RIV	0	-39	-39	0	-31	-31	6	-53	-47	0	-32	-32
FRF	1	-7	-7	0	-7	-7	1	-7	-7	1	-7	-7
FFF	3	-16	-13	3	-15	-13	3	-16	-13	3	-16	-13
FLF	29	-319	-289	29	-322	-293	34	-326	-292	26	-319	-293

Table B.32: 2050WLmax layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	-6	-6	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-10	-10	0	-14	-14	0	-15	-15
RIV	0	-50	-50	0	-33	-33	0	-39	-39	0	-37	-37
FRF	1	-7	-6	1	-7	-6	1	-7	-7	0	-7	-7
FFF	2	-15	-13	3	-16	-13	3	-16	-13	2	-16	-13
FLF	32	-320	-289	24	-324	-300	29	-319	-289	28	-319	-291

Table B.33: 2085GLmax layers 1-4

	2085GLmax			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-15	-15	0	-21	-21	0	-4	-4	0	-19	-19
RIV	0	-41	-41	0	-32	-32	6	-56	-50	0	-34	-34
FRF	1	-7	-7	1	-7	-7	1	-7	-7	1	-7	-7
FFF	3	-16	-13	3	-15	-13	3	-16	-13	3	-16	-13
FLF	31	-321	-291	30	-325	-294	35	-328	-293	28	-322	-294

Table B.34: 2085GLmax layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	-6	-6	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-12	-12	0	-15	-15	0	-16	-16
RIV	0	-52	-52	0	-35	-35	0	-41	-41	0	-39	-39
FRF	1	-7	-6	1	-7	-6	1	-7	-7	1	-7	-7
FFF	2	-15	-13	3	-16	-13	3	-16	-13	2	-16	-13
FLF	33	-323	-290	25	-327	-301	31	-321	-291	30	-322	-292

Table B.35: 2085WHmin layers 1-4

	2085WHmin			Higher water level			Brook swamp			Meandering		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-1	-1	0	0	0	0	0	0
RIV	0	-2	-2	0	-1	-1	24	-7	17	0	-2	-2
FRF	0	-4	-4	0	-4	-4	0	-5	-5	0	-4	-4
FFF	2	-12	-10	2	-12	-10	2	-14	-12	2	-12	-10
FLF	1	-234	-233	1	-235	-234	5	-254	-249	1	-234	-233

Table B.36: 2085WHmin layers 1-4

	Closed ditches			Agricultural abstractions			Effluent infiltration			Less mowing		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	-3	-3	0	-1	-1	0	-2	-2	0	-2	-2
FRF	0	-4	-4	0	-4	-3	0	-4	-4	0	-4	-4
FFF	2	-12	-10	2	-11	-9	2	-12	-10	2	-12	-10
FLF	2	-234	-233	1	-237	-236	1	-234	-233	1	-235	-233

B.2.3. Climate scenarios combined with combined interventions

Landschotse Heide

First aquifer layer

Table B.37: 2050GHmin layer 1

	2050WLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	-2	-2	0	0	0
DRN	0	-1	-1	0	-1	-1	0	0	0	0	-1	-1
RIV	0	-18	-18	0	-20	-20	0	-29	-29	0	-20	-20
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	11	-232	-220	13	-231	-219	22	-230	-208	13	-231	-219

Table B.38: 2050WLmax layer 1

	2050WLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	-39	-39	0	0	0
DRN	0	-5	-5	0	-7	-7	0	0	0	0	-7	-7
RIV	0	-35	-35	0	-39	-39	0	-49	-49	0	-39	-39
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	20	-344	-323	26	-343	-317	62	-337	-274	26	-343	-317

Table B.39: 2085GLmax layer 1

	2085GLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	-41	-41	0	0	0
DRN	0	-5	-5	0	-7	-7	0	0	0	0	-7	-7
RIV	0	-35	-35	0	-40	-40	0	-50	-50	0	-40	-40
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	21	-327	-326	27	-347	-320	64	-340	-276	27	-347	-320

Table B.40: 2085WHmin layer 1

	2085WHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	-2	-2	0	0	0
DRN	0	-1	-1	0	-1	-1	0	0	0	0	-1	-1
RIV	0	-19	-19	0	-21	-21	0	-31	-31	0	-21	-21
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	12	-242	-229	14	-241	-227	23	-239	-216	14	-241	-227

Top four aquifer layers combined

Table B.41: 2050GHmin layers 1-4

	2050GHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	-2	-2	0	0	0
DRN	0	-3	-3	0	-1	-1	0	0	0	0	-1	-1
RIV	0	-60	-60	0	-56	-56	0	-96	-96	0	-56	-56
FRF	10	-25	-15	10	-26	-16	25	-34	-10	12	-34	-22
FFF	31	-85	-55	30	-86	-56	76	-100	-56	41	-108	-66
FLF	19	-125	-106	17	-127	-110	35	-111	-76	26	-120	-94

Table B.42: 2050WLmax layers 1-4

	2050WLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	-39	-39	0	0	0
DRN	0	-16	-16	0	-14	-14	0	0	0	0	-15	-15
RIV	0	-154	-154	0	-130	-130	0	-175	-175	0	-130	-130
FRF	18	-32	-14	15	-34	-20	33	-36	-3	19	-45	-26
FFF	30	-92	-62	29	-96	-67	42	-105	-63	39	-119	-80
FLF	36	-152	-116	31	-163	-132	39	-122	-83	28	-140	-112

Table B.43: 2085GLmax layers 1-4

	2085GLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	-41	-41	0	0	0
DRN	0	-18	-18	0	-16	-16	0	0	0	0	-16	-16
RIV	0	-157	-157	0	-132	-132	0	-177	-177	0	-132	-132
FRF	18	-32	-14	15	-35	-20	34	-37	-3	19	-45	-26
FFF	30	-92	-62	29	-96	-67	42	-105	-63	39	-120	-81
FLF	37	-153	-116	31	-164	-132	40	-122	-83	28	-140	-112

Table B.44: 2085WHmin layers 1-4

	2085WHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	-2	-2	0	0	0
DRN	0	-4	-4	0	-2	-2	0	0	0	0	-2	-2
RIV	0	-68	-68	0	-61	-61	0	-103	-103	0	-61	-61
FRF	11	-26	-15	10	-27	-16	25	-35	-10	13	-35	-22
FFF	30	-86	-55	30	-87	-57	44	-101	-57	41	-108	-67
FLF	20	-128	-108	18	-131	-113	36	-113	-77	26	-122	-96

De Pielis

First aquifer layers

Table B.45: 2050GHmin layer 1

	2050GHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-239	-239	0	-239	-239	0	-239	-239	0	-239	-239

Table B.46: 2050WLmax layer 1

	2050WLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	-19	-19	0	0	0
DRN	0	-6	-6	0	-6	-6	0	0	0	0	-6	-6
RIV	0	0	0	0	0	0	0	-3	-3	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-360	-357	3	-360	-357	17	-357	-340	3	-360	-357

Table B.47: 2085GLmax layer 1

	2085GLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	-20	-20	0	0	0
DRN	0	-6	-6	0	-6	-6	0	0	0	0	-6	-6
RIV	0	0	0	0	0	0	0	-3	-3	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-363	-360	3	-363	-360	19	-361	-343	3	-363	-360

Table B.48: 2085WHmin layer 1

	2085WHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-249	-249	0	-249	-249	0	-249	-249	0	-249	-249

Top four aquifer layers combined

Table B.49: 2050GHmin layers 1-4

	2050GHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	-1	-1	0	-1	-1	0	-1	-1	0	-1	-1
FRF	0	-4	-4	0	-4	-4	1	-18	-17	1	-18	-17
FFF	2	-12	-10	2	-12	-10	8	-30	-22	9	-32	-23
FLF	1	-226	-225	1	-226	-225	0	-200	-200	0	-198	-198

Table B.50: 2050WLmax layers 1-4

	2050WLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	-19	-19	0	0	0
DRN	0	-14	-14	0	-14	-14	0	0	0	0	-14	-14
RIV	0	-39	-39	0	-39	-39	0	-38	-38	0	-44	-44
FRF	1	-7	-7	1	-7	-7	2	-31	-30	2	-31	-30
FFF	3	-16	-13	3	-16	-13	10	-42	-32	10	-43	-33
FLF	29	-319	-289	29	-319	-289	13	-257	-244	12	-254	-242

Table B.51: 2085GLmax layers 1-4

	2085GLmax			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	-21	-21	0	0	0
DRN	0	-15	-15	0	-15	-15	0	0	0	0	-15	-15
RIV	0	-41	-41	0	-41	-41	0	-39	-39	0	-46	-46
FRF	1	-7	-7	1	-7	-7	2	-32	-30	2	-32	-30
FFF	3	-16	-13	3	-16	-13	10	-42	-32	10	-43	-33
FLF	31	-321	-291	31	-321	-291	13	-258	-245	13	-255	-242

Table B.52: 2085WHmin layers 1-4

	2085WHmin			Climate buffer			HW + CD			CB + Effl. Inf.		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	0	0	0	0	0	0	0	0
RIV	0	-2	-2	0	-2	-2	0	-2	-2	0	-2	-2
FRF	0	-4	-4	0	-4	-4	1	-19	-18	1	-19	-18
FFF	2	-12	-10	2	-12	-10	8	-32	-24	9	-34	-25
FLF	1	-234	-233	1	-234	-233	0	-206	-206	0	-205	-204

B.2.4. Climate scenarios combined with abstraction scenarios

Landschotse Heide

First aquifer layers

Table B.53: 2050GHmin layer 1

	2050WLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-1	-1	0	-1	-1	0	-1	-1
RIV	0	-18	-18	0	-20	-20	0	-19	-19	0	-18	-18
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	11	-232	-220	13	-231	-219	12	-232	-220	11	-232	-221

Table B.54: 2050WLmax layer 1

	2050WLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-5	-5	0	-10	-10	0	-6	-6	0	-3	-3
RIV	0	-35	-35	0	-36	-36	0	-35	-35	0	-34	-34
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	20	-344	-323	25	-342	-317	22	-343	-321	19	-344	-325

Table B.55: 2085GLmax layer 1

	2085GLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-5	-5	0	-10	-10	0	-6	-6	0	-4	-4
RIV	0	-35	-35	0	-37	-37	0	-36	-36	0	-35	-35
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	21	-347	-326	26	-346	-320	22	-347	-325	20	-348	-328

Table B.56: 2085WHmin layer 1

	2085WHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-1	-1	0	-1	-1	0	-1	-1	0	-1	-1
RIV	0	-19	-19	0	-21	-21	0	-20	-20	0	-19	-19
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	12	-242	-229	13	-241	-227	12	-241	-229	12	-242	-230

Top four aquifer layers combined

Table B.57: 2050GHmin layers 1-4

	2050GHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-3	-3	0	-6	-6	0	-4	-4	0	-2	-2
RIV	0	-60	-60	0	-78	-78	0	-66	-66	0	-55	-55
FRF	10	-25	-15	12	-19	-7	11	-23	-12	10	-28	-18
FFF	31	-85	-55	29	-87	-58	30	-86	-56	31	-85	-54
FLF	19	-125	-106	24	-114	-90	20	-122	-102	17	-128	-111

Table B.58: 2050WLmax layer 1-4

	2050WLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-17	-17	0	-25	-25	0	-19	-19	0	-14	-14
RIV	0	-154	-154	0	-170	-170	0	-159	-159	0	-148	-148
FRF	18	-32	-14	19	-27	-8	18	-30	-12	18	-34	-16
FFF	30	-92	-62	30	-93	-64	30	-93	-63	30	-92	-62
FLF	36	-152	-116	42	-138	-96	38	-148	-110	35	-157	-123

Table B.59: 2085GLmax layers 1-4

	2085GLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-18	-18	0	-26	-26	0	-20	-20	0	-15	-15
RIV	0	-157	-157	0	-173	-173	0	-162	-162	0	-151	-151
FRF	18	-32	-14	19	-27	-8	18	-30	-12	18	-34	-16
FFF	30	-92	-62	30	-93	-64	30	-93	-63	30	-92	-62
FLF	37	-153	-116	42	-139	-96	38	-148	-110	35	-158	-123

Table B.60: 2085WHmin layer 1-4

	2085WHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-4	-4	0	-7	-7	0	-4	-4	0	-3	-3
RIV	0	-68	-68	0	-85	-85	0	-73	-73	0	-62	-62
FRF	11	-26	-15	13	-20	-7	12	-23	-12	11	-29	-18
FFF	30	-86	-55	29	-88	-58	30	-86	-56	31	-85	-54
FLF	20	-128	-108	26	-117	-91	22	-125	-103	19	-132	-113

De Pielis

First aquifer layer

Table B.61: 2050GHmin layer 1

	2050GHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-1	-1	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-239	-239	0	-238	-238	0	-239	-239	0	-239	-239

Table B.62: 2050WLmax layer 1

	2050WLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-6	-6	0	-11	-11	0	-7	-7	0	-5	-5
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-360	-357	7	-358	-351	4	-359	-355	3	-360	-357

Table B.63: 2085GLmax layer 1

	2085GLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-6	-6	0	-12	-12	0	-7	-7	0	-5	-5
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	3	-363	-360	8	-362	-354	4	-363	-359	3	-364	-361

Table B.64: 2085WHmin layer 1

	2085WHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-1	-1	0	0	0	0	0	0
RIV	0	0	0	0	0	0	0	0	0	0	0	0
FRF	0	0	0	0	0	0	0	0	0	0	0	0
FFF	0	0	0	0	0	0	0	0	0	0	0	0
FLF	0	-249	-249	1	-249	-248	0	-249	-249	0	-249	-249

Top four aquifer layers combined

Table B.65: 2050GHmin layers 1-4

	2050GHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	239	0	239	239	0	239	239	0	239	239	0	239
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-1	-1	0	0	0	0	0	0
RIV	0	-1	-1	0	-9	-9	0	-2	-2	0	0	0
FRF	0	-4	-4	0	-7	-7	0	-5	-5	1	-3	-3
FFF	2	-12	-10	3	-15	-12	3	-13	-10	2	-11	-8
FLF	1	-226	-225	6	-216	-209	1	-223	-222	0	-228	-228

Table B.66: 2050WLmax layers 1-4

	2050WLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	363	0	363	363	0	363	363	0	363	363	0	363
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-14	-14	0	-29	-29	0	-18	-18	0	-12	-12
RIV	0	-39	-39	0	-60	-60	0	-46	-46	0	-33	-33
FRF	1	-7	-7	1	-9	-9	1	-8	-7	0	-6	-6
FFF	3	-16	-13	3	-17	-14	3	-16	-13	2	-15	-13
FLF	29	-319	-289	50	-302	-251	35	-313	-278	25	-324	-299

Table B.67: 2085GLmax layer 1-4

	2085GLmax			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	367	0	367	367	0	367	367	0	367	367	0	367
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	-15	-15	0	-30	-30	0	-19	-19	0	-13	-13
RIV	0	-41	-41	0	-62	-62	0	-47	-47	0	-35	-35
FRF	1	-7	-7	1	-9	-9	1	-8	-7	1	-7	-6
FFF	3	-16	-13	3	-17	-14	3	-16	-13	2	-15	-13
FLF	31	-321	-291	52	-304	-252	36	-316	-279	26	-327	-301

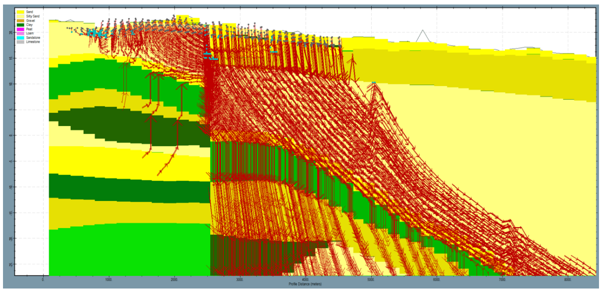
Table B.68: 2085WHmin layers 1-4

	2085WHmin			No abstraction			30% less			30% more		
	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM	IN	OUT	SUM
RCH	249	0	249	249	0	249	249	0	249	249	0	249
OLF	0	0	0	0	0	0	0	0	0	0	0	0
DRN	0	0	0	0	-2	-2	0	0	0	0	0	0
RIV	0	-2	-2	0	-13	-13	0	-4	-4	0	-1	-1
FRF	0	-4	-4	0	-8	-7	0	-5	-5	0	-4	-3
FFF	2	-12	-10	3	-15	-12	3	-13	-11	2	-11	-9
FLF	1	-234	-233	9	-223	-214	2	-232	-229	1	-237	-236

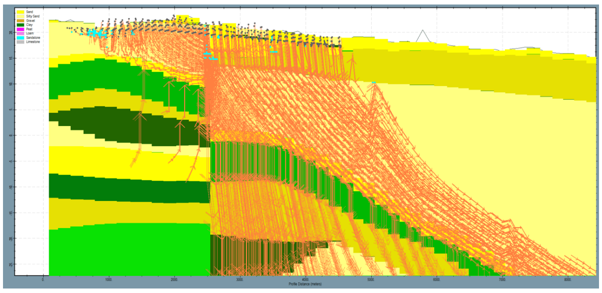
B.3. Flow paths

This section shows the flow paths for the single interventions which are not shown in the report.

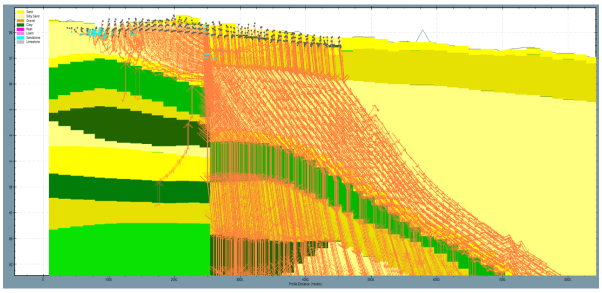
Landschotse Heide



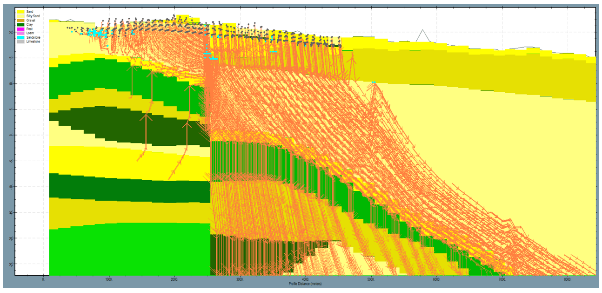
(a) BASE model



(b) Meandering

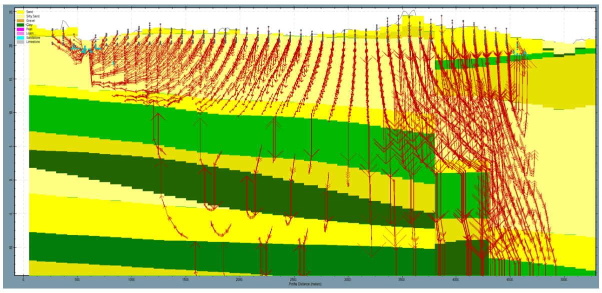


(c) Agricultural abstraction

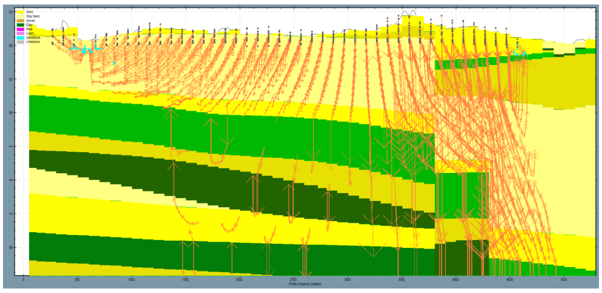


(d) Effluent infiltration

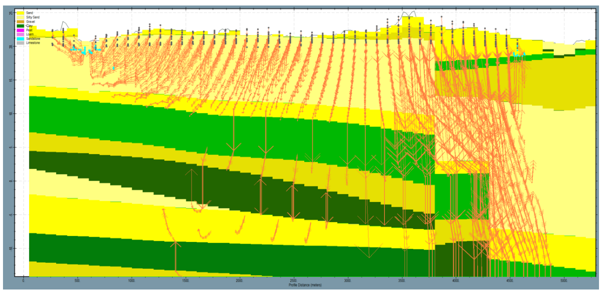
Figure B.101: Flow paths for the Landschotse Heide and its surroundings for the single interventions not shown in the report, for the South-North transect.



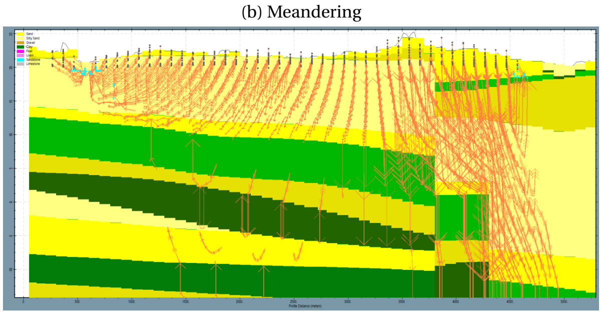
(a) BASE model



(b) Meandering



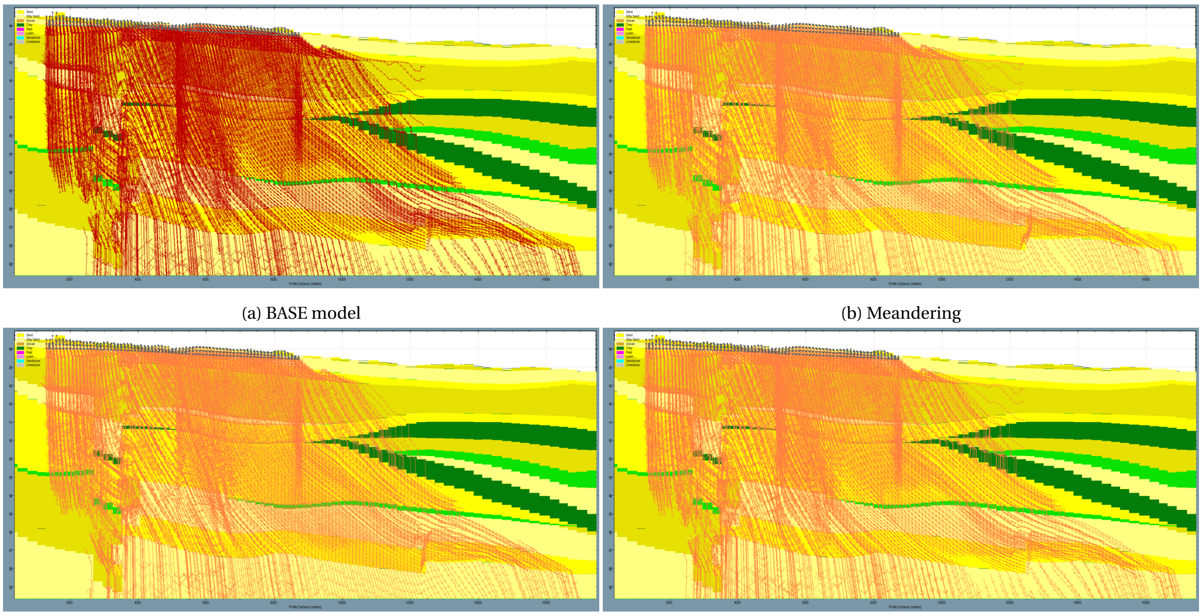
(c) Agricultural abstraction



(d) Effluent infiltration

Figure B.102: Flow paths for the Landschotse Heide and its surroundings for the single interventions not shown in the report, for the West-East transect.

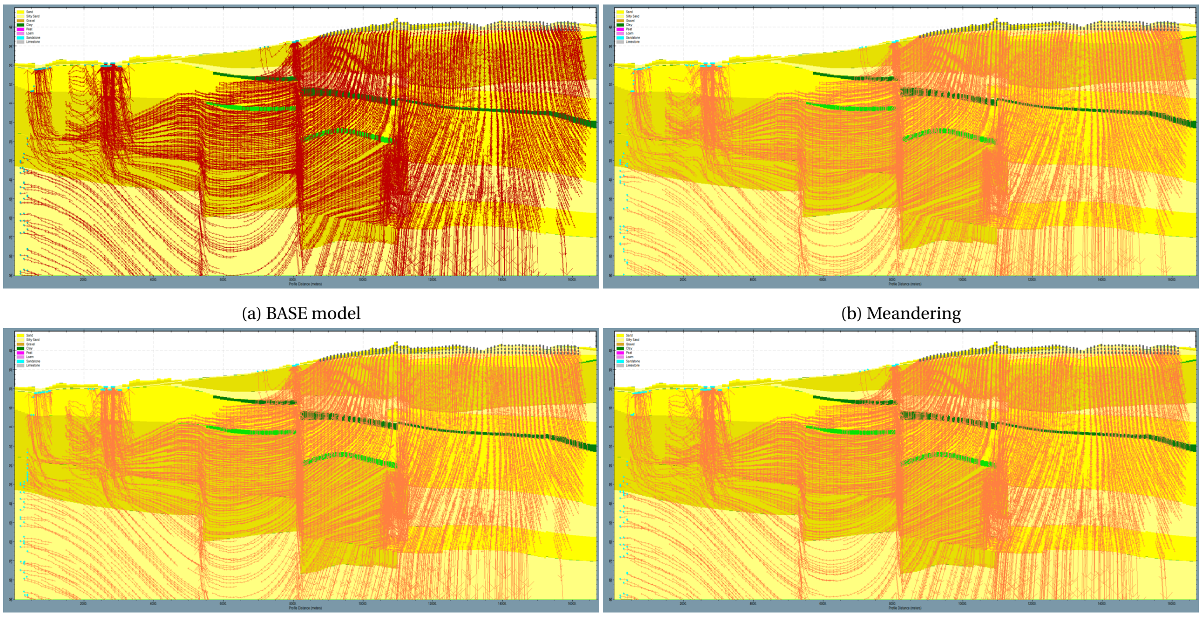
De Pielis



(a) BASE model (b) Meandering

(c) Agricultural abstraction (d) Effluent infiltration

Figure B.103: Flow paths for De Pielis and its surroundings for the single interventions not shown in the report, for the South-North transect.



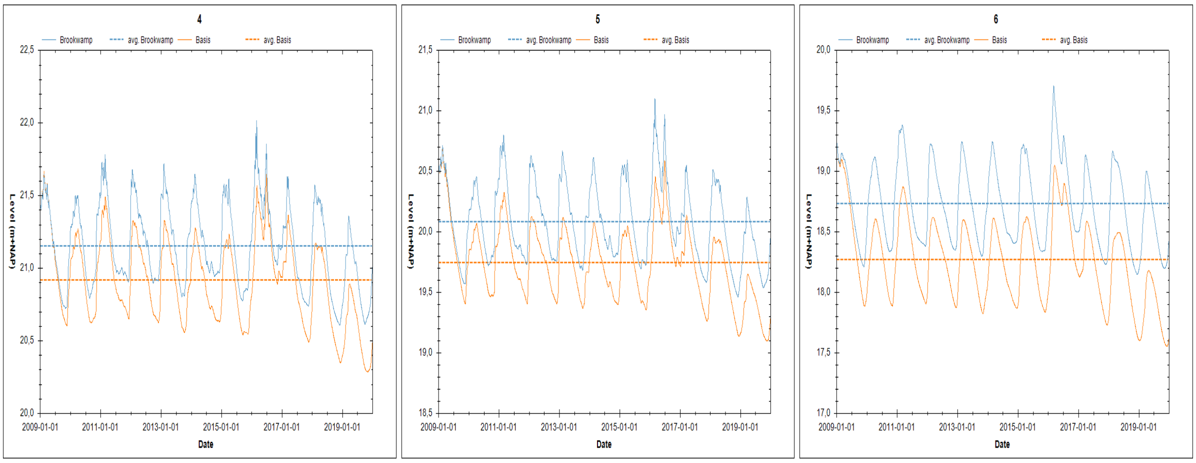
(a) BASE model (b) Meandering

(c) Agricultural abstraction (d) Effluent infiltration

Figure B.104: Flow paths for De Pielis and its surroundings for the single interventions not shown in the report, for the West-East transect.

B.4. Time series

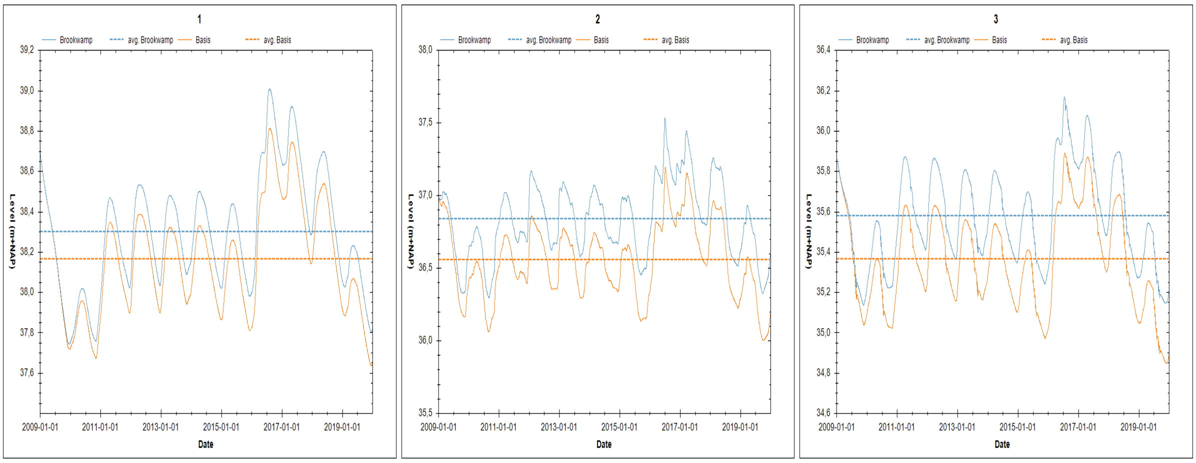
Landschotse Heide



(a) South calculation point (b) Centre calculation point (c) North calculation point

Figure B.105: Time series of the head for the BASE model and the "brook swamp" intervention for the Landschotse Heide for the whole model period.

De Pielis



(a) South-West calculation point (b) Centre calculation point (c) North-East calculation point

Figure B.106: Time series of the head for the BASE model and the "brook swamp" intervention for De Pielis for the whole model period.